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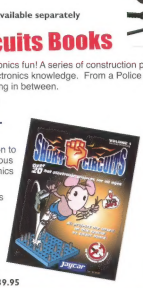

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Contents

Vol.27, No.1; January 2014 www.siliconchip.com.au

Features

12 Arduino-Controlled Fuel Injection For Small Engines
Experiment with electronic fuel-injection for your 4-stroke lawnmower using this simple Arduino-based system – by Nenad Stojadinovic

82 Review: Rigol DS1104Z-S Digital Storage Oscilloscope
Compact, low-cost 4-channel digital scope boasts advanced features that would have cost a fortune not too long ago – by Nicholas Vinen

86 The Sydney Mini Maker Faire
We visit the "Mini Maker Faire", an exhibition of various groups and businesses dedicated to people building stuff – by Nicholas Vinen

Projects To Build

20 Bass Extender Mk2 For HiFi Systems
Want more bass from your speakers? The Bass Extender Mk2 can give a big improvement in bass response for very little outlay – by Nicholas Vinen

30 PortaPAL-D: A Powerful, Portable PA System, Pt.2
Second article on our new go-anywhere portable PA system shows you how to build the PCBs, mount them on two L-shaped aluminium panels and connect them together – by John Clarke

58 Build A LED Party Strobe
Using high-power LED arrays, it's easy to make a safe party strobe which will give a good display yet won't break the bank – by Ross Tester & Nicholas Vinen

68 Li'l Pulser Mk2: Fixing The Switch-Off Lurch
A design flaw in our Li'l Pulser Model Train Controller Mk2 means that at switch-off, any locomotive(s) on the track can suddenly lurch forward, even if they were stationary. Here's how to fix the problem – by Nicholas Vinen & Leo Simpson

88 "Tiny Tim" 10W/Channel Stereo Amplifier, Pt.3
Final article shows how to assemble the unit into the case, complete the wiring and do the testing – by Nicholas Vinen & Leo Simpson

Special Columns

40 Serviceman's Log
A typical day in my working life – by Dave Thompson

46 Salvage It!
Wrecking a dead PC power supply for parts – by Bruce Pierson

76 Circuit Notebook
(1) Pseudo-Random Timer For A Bird Scarer; (2) Universal Numeric Display For Controllers Running Maximite Basic; (3) Door Minder Senses Air Pressure And Plays A Tune

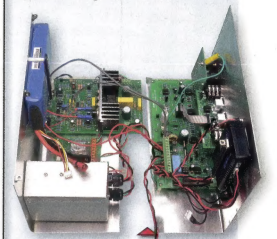
94 Vintage Radio
Philco Safari: the first transistor portable projection TV set – by Ian Batty

Departments

2 Publisher's Letter
4 Mailbag
19 Subscriptions
57 Product Showcase
67 Online Shop
99 Ask Silicon Chip
103 Market Centre
104 Notes & Errata

Arduino-Controlled Fuel Injection For Small Engines – Page 12.

Bass Extender Mk2 For HiFi Systems – Page 20.



Building The PortaPAL-D PA System – Page 30.

Build A LED Party Strobe – Page 58.

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Publisher's Letter

Parcel deliveries by octocopter may be some time off

Just as this issue was going to press there was an announcement that Amazon.com is working on drones for same-day parcel delivery. Just a few days later, there was a similar announcement from Australian company Zookal which offers a service providing secondhand text books to university students. My first reaction to the announcements was "Yeah, right! That's not going to happen, any time soon."

The basic concept is to use octocopters very similar to those featured in our August 2012 issue. Those machines can lift loads of a few kilograms and Amazon.com envisions them being used to make quick deliveries within 10 miles (16km) of their warehouses. And it is perfectly feasible for a drone octocopter to make such a journey. It would only need GPS locations for a few way-points programmed into it and off it would go. Of course, each time it comes back to base, its battery pack would need to be charged, its way-points changed and off it would go again.

But it's not any lack of technical feasibility which will stop this idea. No, it is the sheer number of drones which would be required to even make a fraction of the deliveries that would be made on any day from a large-scale on-line retailer. For a typical fulfilment centre, it would require many hundreds of drones to make even a reasonable dint in the number of deliveries every day. That would mean huge numbers of battery packs always being on charge and so on.

There is also the major problem of making sure that the delivery actually gets to the customer and proving it did. How does the customer sign a delivery docket? And while Amazon has stated that these drones won't carry cameras because of privacy concerns, you can bet that cameras will need to be used to prove that delivery has occurred.

But those are minor problems compared to the possibility of success. Suppose it really was practical for parcel delivery. Can you imagine huge numbers of these octocopters buzzing around a warehouse, like bees to a hive? And if Amazon did it successfully that means that all large courier companies would want to get into the act so we would have literally thousands of drones buzzing around. If you think that aviation authorities have enough problems with the coordination of hundreds or thousands of flights of full-size aircraft over our cities, how would they cope with octocopters flying in the same air space? But the same problems of flight and route control would also have to be handled by the courier companies.

There is no way that our Civil Aviation Authority or the United States' Federal Aviation Authority is going to let that happen.

In any case, a drone carrying a single parcel for each round trip does not seem like a good concept, logistically. For half the trip it won't be carrying anything. By contrast, any courier vehicle probably carries dozens or even hundreds of parcels and has a carefully mapped out course to make the journey as efficient as possible.

Of course, one can well understand the motivation for Amazon or any courier company wanting to use the latest technology to provide quick deliveries to customers. The huge number of on-line sales from internet retailers now means the normal delivery methods are being overwhelmed. Fulfilment companies are looking for any method which will give them an edge in improving their delivery times.

No doubt technology will assist deliveries but I don't think drones are going to be a major part of that scenario. It was a nice bit of publicity for Amazon.com though.

By Leo Simpson

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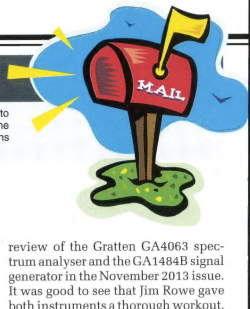

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Electric vehicles could use super-capacitors

Regarding your November editorial, I agree that most current implementations of electric vehicles seem to have little to offer the average motorist. If you could convince people to drive electric cars made of balsa wood and plastic film, you could achieve much the same pollution reductions with similar cars using tiny internal combustion engines!

While lithium batteries are a significant improvement over what has gone before, they still aren't really good enough. However a possible dark horse might be capacitor storage. Capacitors are already being used for regenerative braking storage in production cars and recent developments in nano-scale carbon technology suggest that there is a very real potential for capacitors to completely replace chemical batteries for transport use.

Carbon-based capacitors would seem to have some unbeatable advantages: low material cost and environmental impact, low weight and probably most important, a recharge time comparable to hydrocarbon refuel times.

Most service stations currently offer a choice of gasoline, diesel and LPG bowsers. Perhaps in the future they will also offer capacitor recharge. One way of doing that would to have their own on-site capacitor bank, which is continuously "trickle charged" off the normal electricity grid. Customers would simply "siphon" high-current bursts of charge into their own vehicles' capacitors.

You could even imagine tanker trucks being replaced by "capacitor trucks" if the local power grid wasn't up to the task! (Or even "electricity tankers" carrying charged capacitors from countries where solar power is plentiful).

Keith Walters,
Riverstone, NSW.

Comment: we published an article on supercapacitors in cars in our April 2008 issue.

Gratten spectrum analyser has outstanding frequency accuracy

Firstly, thanks to SILICON CHIP for the review of the Gratten GA4063 spectrum analyser and the GA1484B signal generator in the November 2013 issue. It was good to see that Jim Rowe gave both instruments a thorough workout.

As a follow-up, I thought you might be interested in the frequency accuracy exhibited by the GA4063 Spectrum Analyser that we checked in the lab a few days ago. The GA4063 one year frequency specification is one part in 2×10^{-7} but we beat that by two orders of magnitude! Here's how.

We tried a frequency adjustment tool sent to us by Gratten. The results, in our opinion, were quite astonishing! (Of course, we are somewhat biased!)

The set-up we used was the Gratten GA1484B signal generator on external clock that was fed from a GPS-disciplined rubidium frequency standard. Accuracy is around 1×10^{-11}, several orders of magnitude better than the spectrum analyser's internal 10MHz reference.

We connected the output of the

Anticlockwise route is shorter

The article on building a GPS Tracker in the November 2013 issue quite correctly states that going around Australia in an anticlockwise direction is "shorter, as you are driving on the left side of the road and on the inside of a circle."

This is based on the fact that the journey around Australia can be approximated as travelling around a circle, since *most* of the lefthand and righthand bends cancel out each other.

Of course, the next two questions that arise from that are how much shorter is the distance and does it matter?

To calculate the circumference of each circle we need to use the formula:

$C = 2\pi R$

where

C = circumference of a circle
R = radius of a circle
π = (approximately) 3.1415

Hence, the difference in the circumference of the two circles is equal to $2\pi(R + S) - 2\pi R = 2\pi(R + S - R) = 2\pi S$, where S is the lane separation (note that the size of the major radius does not matter).

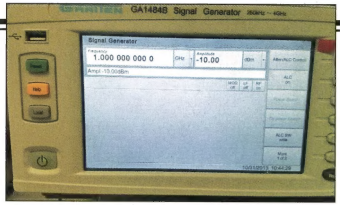
Most of the journey would be on 2-lane roads where a generous estimate of the separation between (the centre line of) vehicles would be four metres. Hence a quite generous estimate of the average separation distance of the traffic lanes throughout the entire journey around Australia might be 10 metres.

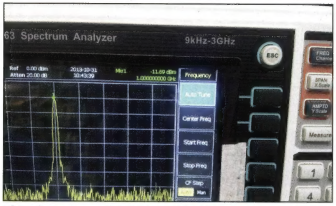
Hence, an upper level estimate of the difference in distance in driving around Australia (or anywhere else) in an anti-clockwise direction as opposed to a clockwise direction would be $2\pi \times 10$ metres, which equals 63 metres.

I doubt if anyone would consider about 60 metres to be significant in any activity involving driving a vehicle over the distance (via the mainland state capitals) of somewhere between 14,000km and 15,000km.

Peter B. Taylor,
Box Hill North, Vic.

Comment: you are correct of course, although the comment in the article was meant to be tongue in cheek.





This photo shows the Gratten GA4063 spectrum analyser measuring a frequency of 1GHz which was produced by a GA148B signal generator locked to a GPS rubidium standard.

GA1484B signal generator to the spectrum analyser's input and fired up the laptop running the adjustment tool. The adjustment tool works by sending a calibration constant to the spectrum analyser. We needed to lock the GA1484B sig-gen to the rubidium standard as both the spectrum analyser and signal generator have similar internal reference accuracies and we needed the generator to be much better than the analyser to get a good test uncertainty ratio.

The spectrum analyser is normally adjusted with a 10MHz input signal and we followed Gratten's procedure to get a solid 10MHz on the display.

We found that at 10MHz the third digit of the cal-constant seemed to have the "tuning effect" on the last digit of the displayed frequency. The two lesser digits in the constant didn't seem to do much at 10MHz. So we tried an undocumented process of setting the generator to 100MHz and lo-and-behold the second least significant digit now had an effect. So we went to 1GHz. We were amazed but by then not surprised when we saw the least significant digit of the constant adjusted the least significant digit in the 1GHz result.

So after some tweaking of the cal-constant we ran out of adjustment and here's a picture of the GA4063 using its internal reference measuring a frequency of 1GHz. The picture says it all – solid zeros indicating a short-term stability of one part in 1×10^{-9}. We are of course now interested to see how the GA4063 holds this calibration point over the coming months.

Charles Holtom,
TRIO Test & Measurement.
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Mailbag: continued

Energy storage via batteries has significant drawbacks

The Publisher's Letter in the November 2013 issue on hybrid cars raises quite a number of food for thought points. As noted there, a vehicle has to carry the fuel that powers it. In addition, on the basis that the fuel's energy is not optimally converted to mechanical energy by present engines, designers have found a means to bolt on engine designs (so-called "hybrid" vehicles) that capture some of the otherwise wasted energy and store it, to be used at other times.

But the presently-available means of storage add significant amounts of weight to the vehicle, in turn requiring additional energy that must be supplied by the fuel to keep the vehicle in motion. The Publisher has said all of that much more pithily than I have here. He also mentioned the not-insignificant matter of the likely increased risks of fire that is present in the use of lithium battery storage technology (and the risk of explosion is raised by your correspondent Peter Bennet in relation to the same technology used in electric drills).

We could raise the same matters of safety (and environmental impacts) in relation to the use of renewables for electricity generation. As well you know, to use renewables in any effective way requires massive amounts of energy storage; storage that has yet to be developed, incidentally.

Even though the weight of the necessary energy storage technologies do not have to be moved around as in a vehicle, there would be the ever-present risk of fire and explosions in some of the proposed technologies (eg, sodium-sulphur batteries).

All of this makes a powerful argument to concentrate our efforts on improving the efficiency of those technologies that provide the energy extraction from the fuel, rather than seek to add what I regard as "band-aids" to address the present lack of efficiency.

Paul Miskelly,
Mittagong, NSW.

Our protected car industry greatly inflates the cost of new cars

I commend you on your Publisher's Letter in the December 2013 issue, on the topic of government subsidies to the car industry.

I wish to highlight the fact that notwithstanding the tariff reductions over the years, it would shock many Australians to discover just how ruthlessly they are being exploited in relation to car prices in Australia. Only a very small minority of Australians are aware that if they went to Japan and purchased a new car at full Japanese retail and then paid for shipping to Australia, plus all the government charges and clearance charges on arrival, that car would be VERY much cheaper than an essentially identical imported new car in any dealer's showroom in Australia.

You don't believe it? I assure you that this information is straight from the mouths of those who know; people in senior positions in the retail imported car sector in this

country. So why don't Aussies buy their new cars overseas and just import direct? Well, quite simply, they cannot!

It is illegal to register a car in Australia that was imported while it was less than 14 years old. The only exception is if you have been living overseas and have owned that car for at least 12 months overseas before shipping it back with you to Australia.

The people of New Zealand and their politicians had a clear understanding of the insane burden that their local car manufacturing system was placing upon them. Their solution was not just to shut down their blood-sucking, self-serving monster of a local car manufacturing sector. That would not have really solved the problem. And make no mistake, they did solve the problem, once and for all.

Well, you may well ask, how did they manage that? Simple, really. They allowed importers and individuals to conveniently and cost effectively import late model cars from abroad. Let's face it, very many people will not go anywhere near a new car showroom if they can get a near new car for a hell of a lot less than a new car costs.

And the distributors and retailers of new imported cars can not get away with overcharging when any private individual can import a near new version of your offering for much less than you are asking.

There are people, primarily in some southern states, who are railing against the down-sizing of the Australian car manufacturing sector (yes, its only a threat of down-sizing at the moment, not the obliteration of that sector that Australians should have demanded, and gotten, long ago). Those same people have never had any sympathy whatsoever for the millions of ordinary Australians who have been paying through the nose for cars, new and used, for many decades. And what an irony many of those peoples attitudes constitute: supporting the craziest forms of corporate welfare. How could we ripped-off car consumers have ever had any sympathy for them, let alone continue to have any sympathy for them?

Once again, New Zealand has shown the way. When it comes to local car manufacturing, it is long overdue that we follow the lead of our friends across the ditch.

Otto S. Hoolhorst,
Brisbane, Qld.

Float charging for car battery

With reference to the reader's enquiry headed "Concern About Car Battery Drain" in Ask SILICON CHIP (page 99 in the September 2013 issue), I am reminded of a similar problem I experienced a few years ago. My Toyota Corolla does not get used very often, sometimes going a week between shopping trips, and consequently the battery was losing charge whilst parked. After having starting problems a number of times, the battery eventually failed prematurely. After fitting a new battery, I investigated the parasitic drain on it when the car was not in use.

The car's own three parasitic drains (engine control unit, radio and clock) only totalled about 10mA but the alarm system brought the total drain up to about 50mA. Many battery manufacturer's websites recommend not letting the battery voltage fall below 12.5V, since sulphation will set in below this voltage and thus shorten battery life. Despite

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Mailbag: continued

the fact that 50mA doesn't sound much for a normal car battery, investigation showed a fully-charged battery would fall to 12.5V in only about three to four days.

My solution was to keep the battery on float charge whenever the car is left standing unused, even just overnight. I now use a small plugpack automatic battery charger designed for sealed lead-acid batteries (Jaycar MB-3517). This charger checks the battery voltage at short intervals and maintains a float voltage of 13.6V. I have had no further trouble and expect a long battery life.

Ross Stell,
Kogarah, NSW.

Discrepancy between photos and circuit

With regard to the GPS Tracker project in the November 2013 issue, I note that the parts list specifies three 82Ω resistors and one 47Ω resistor. This is confirmed by the circuit and PCB layout diagrams. However, the two photos show that four 47Ω resistors are used on the PCB and there are none which are 82Ω. So which is correct?

Russell Shepherd,
Epping, Vic.

Comment: the circuit is correct and 82Ω resistors should be used where specified. The values were changed from the prototype because we determined that the current which would flow from the relevant microcontroller pins was in excess of the rating. Perhaps we should have doctored the photos to avoid confusion amongst eagle-eyed readers.

As an aside, our first batch of the PCBs for this project did have three current limiting resistors shown as 47Ω but this has been corrected in a later batch.

Diesel-electric loco technology

With reference to Alan Bothe's letter on diesel electric locomotives (Mailbag, page 6, December 2013), the choices the engineers made when they developed the GM/Holden Volt answer the question of whether a hybrid car would be better if it eliminated the mechanical gearbox and adopted the architecture of diesel-electric locomotives, ie, a petrol engine driving a generator, the power from the latter driving an electric motor and it, and it alone, driving the wheels. That was what GM wanted to build, if for no other reason than to differentiate their car from Toyota's Prius. To be able to say they hadn't just copied it; they had built something better.

Unfortunately it is a less efficient configuration than a gearbox. And they couldn't meet their highway fuel consumption targets. So in the final production version, the electric motor drives the car at slow speeds but at higher speeds the petrol engine directly drives the wheels. Each motor does what it does best. The electric motor's maximum torque at zero revs is used to pull the car away from stationary. But on the highway at constant speed, the petrol engine is working at its most efficient revs through an efficient direct connection to the wheels.

Using the best electric drive, there would be 4-5% loss in the generator, the same again in the controller and the same again in the electric motor. By comparison, the losses between the flywheel and road are only 11% in a conventional front-wheel drive, 14-15% in a rear-wheel drive car and 17-19% in a 4WD. And a lot of that is in the tyres and differential(s) which an electric motor powered car would have anyway.

Weight isn't an issue in a locomotive. It needs to be heavy to get enough traction to tow a train. An electric drive-train capable of 75kW sustained output and bursts of 100kW in a car would require a 75kW petrol engine powering a 75kW generator, a controller that could handle 100kW and an electric motor rated at 100kW. Minimum weight and cost are a lot more important in a car.

Engineering things so that the petrol motor and electric motor can both send their power to the wheels together would mean a hybrid drive of the same performance would only require a 75kW petrol engine, a 25kW controller and a single unit that could act both as a 25kW motor when accelerating and a 25kW generator when braking or charging charge the battery.

Gordon Drennan,
Burton, SA.

Refrigerator compressor not ideal for a vacuum pump

With reference to the letter on making a vacuum pump (Mailbag, page 100, December 2013), there are some significant problems with making a vacuum pump using a

sealed unit refrigeration compressor.

Firstly, the vacuum input of the sealed unit opens directly into the 'dome' of the sealed unit, so the interior of the dome is normally flooded with the (cold) gas returning from the fridge after cooling the food, and this is responsible for cooling the windings of the electric motor that drives the compressor. When the sealed unit is operated as a vacuum pump, all the air is extracted from inside the dome, and there is nothing left there to cool the motor windings, which may burn out in fairly short order if the motor is left running with a vacuum inside.

It is feasible to use the sealed unit as a vacuum pump for something like a solder sucker but either (a) the motor should be shut down once the vacuum reaches the required low pressure or (b) the dome should be flooded with air when the vacuum is not required, between 'sucking' operations. Option (a) is going to require a pressure switch to stop and start the motor and the motor may have to start many times in a short period with little or no cooling available to it (which is not what they are designed for). Option (b) requires some extra plumbing to release the vacuum after each 'suck' and then spend some time re-evacuating it before the next task, still with inadequate cooling.

Also, some of the smaller sealed units use a PTC thermistor to 'cut out' the starting winding once the compressor has run up to full speed, and this thermistor takes several minutes to cool after each start. If started frequently, the motor may not start reliably with a hot thermistor and again increase the risk of releasing the magic blue smoke from the windings of the motor and destroying the compressor unit.

Lastly, refrigeration compressors are designed to pump a significant amount of oil around the refrigerator system with the refrigerant gas, to help seal porous welds etc, and this continuous loss of oil when running as an open outlet vacuum pump will eventually drain the compressor and cause a mechanical failure.

I suspect that the compressor motor will have a fairly short and unhappy life if it is used as a vacuum pump and unless the users have a source of cheap compressors, they will find it an expensive design to run in the long term.

Brian Spencer,
Seaford, SA.

GPS HUD solves speedo accuracy problem

I read the letter requesting a head-up display for pre-OBD cars (Ask SILICON CHIP, December 2013, page 98) and also the comments in your earlier article on HUDs in the September 2013 issue, concerning "drop outs" and slow start up with GPS HUDs. Well, I have fitted a GPS HUD to my 1978 Corvette Stingray, mainly because the dash lights are too dim at night and the speedo is predominantly in MPH.

Problem solved! I plugged it into a spare 12V source and hey presto, after initially zeroing it once only, every time I start the car it's up and running. I checked it against my Tom Tom GPS unit and it's identical. I cannot say the same for my original cable drive speedo, which was up to 5km/h out.

I had to face it slightly off centre so that it's not distracting in my line of vision but it has never dropped out or not operated immediately. This quick fix has allowed me to drive it at night while I sort out the dash lights problem which prevented me reading the mechanical speedo.

Thanks to SILICON CHIP for putting the idea in my head with your HUD articles previously.

Ray Preston,
Hillier, SA.

Interior door lights should be amber-tinted

I have read your article on LEDs in cars (December 2013). I realise that the headline stresses interior lights but then you go on to change the lights in the doors. My understanding has been that the orange or amber light in the door is to warn approaching traffic that there is an obstruction if a door is left open. The only car I have ever had with door lights, a Toyota Crown, probably

Mailbag: continued

Upgrading a drill battery pack with Lithium Polymer

Following on from the September 2013 article on converting battery packs for battery-powered drills, etc, I upgraded my much-loved GMC 18V unit. Going through the Hobby King website, I selected an 18V/2200mAH pack as being the best fit for my GMC housing. The housing, as you may observe in the picture, is rather tight and structured fairly rigidly, so fitting a larger capacity pack would have been nearly impossible. The pack I chose was the Turnigy T2200.5S/6589.

I also purchased the "Genuine" IMAXB6 charger/discharger for 1-6 cells. After receiving the main items I then needed to make up an adapter lead for charging/discharging the pack, so I bought the connector packs, 606A-606B Nylon T-connectors and XT60 Nylon XT60 connectors. As well, I bought the GT-BMON6 battery monitor which was only $2.11.

Next step was to fit it all into the battery pack. I didn't have any problems as discussed in the September article as I don't have a case to pack the drill into but the leads seemed to want to exit via the front of the pack anyway.

At this stage I haven't used the "battery saver" module and I used a 3AG 30A fuse and 3AG holder. I'm hoping the fuse will blow before meltdown occurs should a fault situation arise. Compared to the lithium cell repack I performed on the other pack several years ago, this provides a much cheaper and hopefully more reliable option.

Another good aspect of the upgrade is weight. The original lithium pack weighs 800g while the new pack weighs just 430g.

Bob Forbes,
Forest Hill, Vic.

in the seventies, had red lights. Maybe things have changed.

One might think that a brighter white light would do the job better but showing a white light to the rear is a no-no. Some years ago I was a volunteer ambulance officer called to a car accident. A car towing a caravan had broken down and a driver wanting to help had positioned his car facing into the engine bay, thus showing white lights to the approaching traffic.

A driver of a truck, about 30 tonnes in those days, saw white lights ahead of him so lined up to go to the left of them. Think about it; that's how we do it normally. By the time he could see the real situation it was too late. He tried to pull back to pass the parked vehicles on his left but wiped out the caravan and car, killed two people and took the lower leg off another.

The fitting of LEDs is a good idea but there is more to it than just getting a brighter light. Some might be tempted to follow up with brake and tail lights which need to be at different brightnesses, another potential death trap if not done properly. It would be interesting to see what ADR (Australian Design Rules) has to say; I suspect your door lights might be mentioned too. Any change to a motor vehicle

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LED lighting in cars may increase road risk

The LED modifications to car interior lighting suggested the December 2013 issue of SILICON CHIP may increase road risk. You would be aware that night (scotopic) vision is a function of the rods in the retina. The rods are the more sensitive receptors to light and movement. However, they take up to 30 minutes to fully re-polarise after exposure to white light.

They are less receptive to light towards the red end of the spectrum. Rods do not respond to red light – only the cones do – hence the use of red light in military night map reading situations so that nocturnal vision (rod function) is preserved.

Increasing the intensity and spectrum of vehicle interior lighting would result in poorer night vision in the immediate period after exposure – in particular peripheral movement awareness would be compromised.

Henry Berenson,
via email.

Comment: we agree that the interior lighting should not be too bright and have said as much in the article. In any case, one should not drive with any of the interior lights on so there should be no increased driving hazard. Also we think the problem is fairly minor, relative to the fact that all drivers are now being subjected to intense white light from on-coming headlights which can be halogen, high-intensity discharge (HID) or white LED. The situation is worse when some cars have their fog lights on as well.

In addition, drivers are subjected to the same onslaught via their rear-view mirrors, both interior and exterior. This is particularly galling when so many drivers seem to have the lights on high beam.

must be in line with the ADRs.

Keep up the good work but watch out for the traps.

Graeme Burgin,
Ararat, Vic.

Comment: we have never seen amber or orange-tinted lenses in the door lights for any cars although we understand some cars have green lenses. Nor is there any regulation that we know of that stipulates that interior door lamps should be amber-tinted. We have checked Australian Design Rules and found no mention of this aspect.

Perhaps we may have confused readers by saying that the interior lamps looked "orange". In fact, we were referring to normal small incandescent lamps which actually do look "orange" by comparison to white LEDs.

They are "white" by the definition you are referring to and they are fitted as standard equipment in the doors of many cars. We really do not think that any driver seeing the low-powered light in an open car door could ever confuse them for headlights of an oncoming car.

We should also point out that the published photos should not be regarded are as a true colour rendition; they merely depict a relative comparison. Our CMYK 4-colour printing does not enable us to correctly reproduce orange or green.

On the subject of brake/tail lamps and traffic indicator lamps, any attempt to substitute LED lamps will be registered as a fault in the brake light circuit in modern cars and the LED radiation pattern may also mean that the brake lamps are less visible when not viewed from directly behind the car.

The same comment applies to attempted substitutions of LEDs for direction indicators, as the switcher unit will behave as though it has a blown lamp and flash the indicators very rapidly.

It also seems possible that replacing the boot lamp in some cars can cause problems with the body computer. SC

Issues Getting Dog-Eared?
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For experimenters . . .

Arduino-controlled fuel injection for small engines

By NENAD STOJADINOVIC

Build a fuel injection system for your lawnmower or give yourself an advantage at the local kart track. This simple Arduino based system will allow you to take control of your small 4-stroke engine and wring the maximum amount of power and economy from it.

IT'S TRUE, there seems to be an inexorable drift towards electric vehicles and machinery but small petrol engines are still very much in evidence and look to be around for a long time yet. There have been some moves to make them more efficient and less polluting but the fact remains that as automotive engines and industrial processes improve, small engines rise in relative significance as a source of harmful emissions.

Part of the problem is that small engines generally run on petrol and it's difficult to burn it completely in a simple, cheap engine. This means that an ability to run on a variety of cleaner fuels, especially the renewable variety, would go a long way towards solving what is becoming a pressing problem. What's stopping us? Mostly it's the carburettor.

Carburettors are seemingly simple devices– after all, how difficult can it be to accurately mix a certain percentage of fuel into a stream of air? Unfortunately, the answer is "very difficult to do mechanically".

A carburettor (that is carefully chosen) for a particular engine is designed to operate on a specific fuel and is a finely crafted and carefully-balanced instrument. In the old days of carburetted cars, the hot-rod fraternity would spend countless hours fussing over jets and pumps and compensators,

trying to achieve a system that worked effectively across the entire rev range. The results were not always perfect but at least it kept them off the streets at night.

Enter this Arduino-controlled fuel injection system. It's a simple and very cheap design that will allow you to tune your engine in any way you want, for almost any fuel. The prototype that is the subject of this article, for example, is designed to burn LPG but could have just as easily run on natural gas (CNG), hydrogen, butane or pretty much anything else that fits into the category of "flammable gas".

Similarly, swapping out the gas injector and adding a small fuel pump and regulator would allow the engine to run on any flammable liquid. The most popular candidates here are members of the alcohol family, such as ethanol and butanol.

Fundamentals

The original version of this project used a petrol fuel-injector from a small car. However, this also needed a fuel pump and pressure regulator – not difficult to organise but the extra parts add a surprising amount of expense and complication. And so, as is my wont, I mulled the design over while idly flipping through various manufacturers' web sites and eventually came across the neat little injector shown in Fig.6.

Strictly speaking, this uses a solenoid valve rather than a conventional injector, which is a valve and spray nozzle in one unit. As such, it's fairly unremarkable, except that it's designed to switch the flow of LPG vapour or CNG at speeds to suit an internal combustion (IC) engine.

What's more, it's designed to give a long service life, unlike a conventional gas solenoid which would rapidly burn out with such harsh treatment.

The end result was an injection system that was simple and rugged and allowed me to use LP gas that has an octane rating of about 112 – cheap and with huge potential for high performance. Or I could set up a methane digester and run the engine on natural gas . . .

Arduino injection

As mentioned, there is nothing particularly difficult about mixing fuel into an air-stream unless one tries to do it accurately. So how exactly do

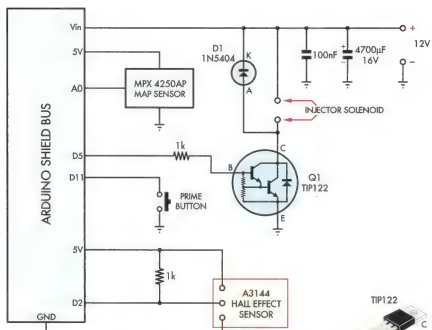


Fig.1: a Freetronics Arduino Shield forms the basis of the design. It accepts inputs from a MAP sensor and a Hall effect sensor (triggered by a magnet on the flywheel) and drives the fuel injector solenoid via transistor Q1. The Arduino Shield also provides a 5V rail to power the sensors.

electronic fuel-injection systems meter precisely the right amount of fuel into the intake air?

At the most basic level, the fuel delivery pressure to an injector is fixed and so the amount of fuel injected per cycle is simply determined by how long the injector opens during that cycle – perhaps a couple of milliseconds at idle and a few tens of milliseconds at full power. That's easy enough in theory but the question is, "just how many milliseconds"?

Fortunately, like a lot of things in the field of engineering, there's a simple answer to this question.

Generally speaking, combustion engineers strive for a "stoichiometric" mixture, which is where every fuel molecule meets up with exactly the right number of oxygen molecules in the air for a complete chemical reaction (ie, complete combustion). Again, the concept is easy to understand but the quantities need to be measured by weight and not volume.

Determining the weight of a liquid fuel flowing through an injector isn't too difficult but determining the mass flow rate of a viscous, temperature-dependent, highly-elastic gas such as air as it passes through an engine isn't so easy. In fact, this problem probably made the early pioneers want to throw a spanner through a window!

It should thus come as no surprise that, over the years, many different ways have been devised to arrive at the correct air/fuel ratio. In this case, I chose the speed-density method which depends on an old friend from high school – the perfect gas law:

PV = nRT

Just for a change, this is a simple equation which states that the air flowing through a system will try to adjust its pressure, volume and temperature so that PV/T is equal to a constant. In this case, V is the volume of the engine cylinder and P & T are the pressure and volume of the air in that cylinder.

It's also possible to further simplify things by assuming that the ambient air temperature remains a constant. In other words, imagine that it's always a nice sunny day with a temperature of about 25°C.

If you then push the numbers around a bit, you'll soon realise that the number of air molecules entering the cylinder (that's the 'n' part of the equation) is simply proportional to the pressure in the cylinder. Easy!

Thus a cylinder that contains 200mg of air molecules at a fairly standard

Fig.2: the fuel supply system. It's basically a gas bottle fitted with a high-pressure regulator and a home-built blowtorch with the burner head removed and a fuel injector attached instead! These parts are available both new and secondhand at very reasonable prices, eg, on-line and from welding shops. Note that a high-pressure regulator must be used. A barbecue regulator produces much too low a pressure and omitting the regulator altogether will destroy the injector solenoid.

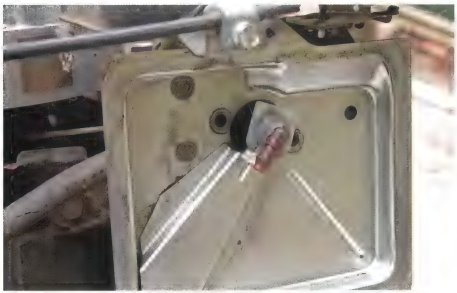


Fig.3: the injector head. Using gas makes life very easy as there are no issues with vaporisation and you don't need a fine high-pressure nozzle to atomise the fuel. In this case, the nozzle is a simple 6mm irrigation fitting (available from hardware stores) glued in place with JB Weld epoxy.

atmospheric pressure of 101kPa will only contain 100mg at 50kPa. And from there you can supply a corresponding number of molecules of fuel by simply programming how long the injector stays open per cycle.

Measuring pressure in the cylinder is done by a Manifold Absolute Pressure (MAP) sensor which fairly reasonably assumes that the pressure in the intake manifold is the same as the pressure in the cylinder – hence the 'M' part of MAP.

In practice, of course, things are never quite that easy. It's easy to imagine that an engine operating at a wide open throttle (WOT) will fill its cylinder with air at full atmospheric pressure, that all the exhaust products from the previous combustion cycle have vacated the premises, and that the manifold pressure is exactly the same as the cylinder pressure. However, this is generally not the case.

As a result, there is an extra factor introduced called "volumetric efficiency" (VE) which essentially measures just how far the engine is straying from theoretical predictions. It's technically referred to as a "fudge factor".

Maths for real engines

Finally, we arrive at an equation that can eventually be turned into software:

PulseWidth = AirFuelRatio x MAP x VE[RPM] + OpeningDelay

- PulseWidth is the length of time that the injector is delivering fuel and is generally measured in milliseconds.
- AirFuelRatio is the desired mass air-fuel ratio, with 14.7:1 used as standard for petrol and about 15.5:1 for LPG.
- MAP is the manifold absolute pressure. In use, it's normalised so that 0 is full vacuum and 1 is standard atmospheric pressure.
- OpeningDelay adds a factor to compensate for the small delay between electronically switching on an injector and having it fully open.
- VE[RPM] is an array of values that estimates just how far the engine deviates from the calculated air-flow at a given RPM. A value of 100 means that it is pumping the full theoretically calculated amount of air, while 0 means that the pistons have fallen out or that the engine is otherwise dead! VE seems to be a bit of a black art amongst the tuners but is really just a measure of how many air molecules actually flowed into the cylinder versus the number you were expecting.

One of the complicating factors with VE is that it is highly dependent on the engine speed and so it is necessary to develop an array of VE values that are indexed according to RPM and placed in a look-up table.

Just how much effort is put into a VE table is largely governed by the engine's intended use. An engine that spends most of its time operating over a small range of engine speeds can get by with only a rudimentary VE table. Conversely, a go-kart engine might need a great deal of effort spent with a laptop and a dynamometer to come up with the required VE for a wide range of speeds.

There are, however, other avenues

that the experimenter can follow to make the process easier and more accurate. These are discussed later in the article.

Engine calculations

For a test bed, I used an old lawnmower that's powered by a venerable 190cc Briggs & Stratton 4-stroke engine with a governed operating speed of 3100 RPM. The following outline of the procedure used to establish its injection parameters is a good example of the process involved for any engine.

As stated, the Briggs & Stratton engine is a 4-stroke unit, so the engine will take two revolutions to pump 190cc of air through the cylinder. That's an average of 95cc per rev. Thus at 3100 RPM, it will pump a total of: $95 \times 3100 = 294.5 \times 10^3$cc/minute or 294.5×10^{-3} cubic metres per minute.

That's the volume of air but we want the mass, so applying the density of air at 1.3kg/m^3 gives the mass of air molecules flowing through the engine as 383g/minute.

The flow rate per minute is useful but engineers tend to like the numbers per second, so dividing by 60 gives the mass of air molecules flowing through the engine as 6.38g/s @ 3100 RPM.

The "fuelling rate" then follows by simple division. For a mixture ratio of 14.7: 1 (ie, petrol), the injector needs to pass 0.43g/s and at 15.5:1 (LP gas), it must pass 0.41g/s. Petrol has a density of about 600mg (milligrams) per cubic centimetre, so 0.43g/s amounts to 0.72cc/s.

There is a bit of a complication in that LPG is usually measured as a vapour which, according to standard tables, has a density of 1.882×10^{-3}g/cc at room temperature and pressure.

So the volume of gas required is $(0.41\text{g/s})/(1.882 \times 10^{-3}\text{g/cc}) = 218$cc/s of LPG at 3100 RPM.

That's a lot of gas volume for less than half a gram of mass per second and I was a bit taken aback by the sheer quantity. As a result, I investigated this further by simply running the engine with a direct feed from the gas regulator and needle valve (ie, no solenoid).

Once I had the flow adjusted for full throttle operation and the engine had settled into a steady roar, I stopped the engine and measured the amount of gas being fed over timed intervals into a balloon. Sure enough, the balloon expanded at a rapid clip and measurement of the resulting gas volume showed that the engine was consuming around 600cc every four seconds, or about 150cc per second. Dividing that result by the calculated value gives $150/218 = 0.69$, or a VE of 69%.

You might get a VE that's close to 85% for a brand new Honda but 68% is not bad for a 30-year-old mower that was bargain basement even when new!

Fig.4(a): the Hall effect sensor mounting. A hole is drilled in the cowling and the sensor is mounted in line with the trigger magnet. Just be careful of magnet polarity and check that the sensor is triggered by the magnet that you intend to use – there are several on the flywheel.

Fig.4(b): Hall sensor mounting details. The sensor was mounted inside a roll of paper that was first spread with PVA glue and then wound around a screwdriver. Once it was dry, it was superglued to an aluminium backing plate and the sensor potted in epoxy.

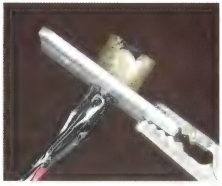


Fig.4(c): side view of the Hall sensor assembly. The rolled tube was cut to length with a razor blade and a small notch cut in the end for the sensor.

The hardware

When it came to devising suitable hardware, I started with the injector and regulator. As can be seen from Fig.2, the fuel-flow hardware essentially consists of only two parts and is really just a plumber's LPG blowtorch with the tip removed.

It's not possible to use a standard barbecue regulator as they don't supply enough pressure. However, adjustable high-pressure regulators are readily available on eBay for around $20, or you can buy really nice ones via Aliexpress for around $32. Or you can break down and visit a welding supply shop and buy one for $60.

The injector solenoid was approximately $20 (from China) and it's important to use one specifically designed for this type of use (an ordinary fuel cut-off solenoid is not suitable for the job and will rapidly self-destruct). An injector solenoid is also designed to run from higher pressures than conventional LPG systems and the

Fig.5: the MAP sensor tap consists of a 4mm right-angle irrigation fitting that's pushed into a hole drilled in the intake manifold, just behind the carburettor. It's also held in place with JB Weld epoxy.

manufacturer of the unit I obtained recommends a range of 0.8-2.5 bar (multiply by 100 for kilopascals).

I needed a way to mount the injector head to the carburettor inlet and Fig.3 shows the simple system I employed. The use of gas allows certain liberties (gas won't re-condense and form pools of raw fuel) and so the "high-tech" injector head is simply a sprinkler fitting epoxied into a hole that I drilled into the carburettor filter housing.

Doing it this way means that the carburettor is completely unmodified and only acts as a throttle body. As a result, the carburettor only changes the manifold pressure but doesn't supply fuel. Doing it that way has an interesting side effect in that it allows you to switch between gas and, say, ethanol by switching off the injector solenoid and turning on the liquid fuel tap.

Lawnmowers don't have crankshaft sensors but they do have magnetos that employ flywheel magnets to generate spark energy. With a bit of disassembly I found that I could trigger a Hall effect sensor very nicely from the flywheel and that it was very simple to mount the Hall sensor to the cooling shroud – see Fig.4.

The final step was fitting a port for the MAP sensor and another sprinkler fitting was pressed (and epoxied) into service. Alternatively, the RC model fraternity has this sort of thing well covered. For only a few dollars, your local model shop can sell you a drill and matching tap to fit a standard fuel nipple into the inlet manifold.

I was a bit concerned about the metal swarf that fell into the manifold when drilling the hole, so I vacuumed it out with a special micro vacuum-cleaner that I made by jamming a plastic tube into a pre-drilled rubber cork which was then pushed into a vacuum-cleaner hose (brewing suppliers sell rubber corks very cheaply).

Fig.5 shows the finished manifold fitting.

Electronics hardware

The electronic circuitry turned out to be very simple and it was equally easy to build the whole lot onto an Arduino prototyping shield from Freetronics.

The Arduino Uno directly drives a TIP122 transistor via a 1kΩ resistor which limits current to the base. The solenoid is designed to be driven directly from 12V and is connected between Q1's collector and the 12V supply rail. Q1 operates in open-collector mode and switching it on simply connects the bottom of the solenoid to ground.

As the solenoid switches off, the collapsing magnetic field generates a large voltage (ie, back EMF) across Q1. This is shunted by diode D1 across the injector, to protect the transistor from damage.

In a similar vein, the two capacitors across the supply rail moderate current surges and bypass any high-speed transients when the relatively large solenoid switches on and off.

The MPX4250AP MAP sensor is commonly used by experimenters and will measure both positive and negative pressures, which is a real boon for turbocharger aficionados. And yes, a turbo is most definitely capable of increasing the VE to levels that are well over unity.

This MAP sensor is very easy to use, as it only requires a 5V supply and outputs a voltage that's proportional to absolute pressure. Note, however, that the output is referenced to the supply voltage and so, to ensure consistency, the supply voltage should be accurately controlled. For experimental purposes, it's not particularly important as there are much larger errors to deal with but a mass-produced version would have a regulated 5V supply.

As can be seen from Fig.1, in my case the MPX4250AP MAP sensor is powered from the Arduino's on-board power supply and its output is read by the A0 pin which has a 10-bit resolution.

The Hall effect sensor is an A3144 device that's intended for use in harsh and hot environments. Hall effect sensors need a power supply and the output is generally open collector so they need to be connected to the supply rail via a pull-up resistor (in this case, 1kΩ). In operation, the sensor's output sits at the supply voltage until triggered by a magnet, whereupon it shorts the bottom of the pull-up resistor to ground.

By the way, Hall effect sensors will only switch for the correct magnetic pole! Applying the wrong pole or applying it to the wrong side of the sensor will have no effect. Also, be aware that some sensors do not necessarily have the pin-out depicted in the data sheet – check it with a magnet once it's all together.

And really, that's all there is to it except for an optional priming button that manually opens the solenoid to give a bit of help when starting the engine.

Software

The software "sketch" (VE_Fuel_Injection.ino) that runs it all is not that fancy but it's good enough for most applications. It's also perfectly good enough for extensive experimentation and as a base for further development.

The code is self-explanatory for the most part and is based around two sep-

arate interrupts. The first is triggered by the Hall sensor on each revolution of the crankshaft, at which point the interrupt service routine activates the solenoid and starts the timer that will eventually deactivate it.

Note that the injector triggers on every revolution of the flywheel. That's exactly what's required in a 2-stroke engine, because there's a power stroke for each complete turn of the crankshaft. By contrast, 4-stroke engines are different because the flywheel rotates twice for each firing cycle. This means that the injector attached to the old Briggs & Stratten engine will inject half the required fuel into the manifold during the intake cycle and the other half during the exhaust cycle (although the intake valve will be closed during exhaust stroke).

This may seem wrong but it's commonly done in engines of all sorts and works well, due to the strange elastic properties of air as it flows into the manifold. It is, of course, possible to sense if the engine is on its exhaust or intake cycle and trigger the injector accordingly but doing so would only add complication without gaining much reward.

In addition, the spark-plug also fires once per rev – once to ignite the mixture and once into a cylinder of exhaust gasses. Again, this is common practice, even in some car engines.

Second interrupt

The second interrupt is based on Timer 1, which is a 16-bit timer that shuts off the solenoid when it reaches a calculated value. Left to its own devices, Timer 1 counts to 65,535 before rolling back over to zero; a process that takes 4ms given the processor's clock speed of 16MHz. However, the injector can only be driven for 80% of that time without overheating (ie, it has an 80% maximum duty cycle).

At an engine speed of 3100RPM, the crankshaft interrupts occur at 51.6Hz. Rearranging things a bit and doing some maths, the Hall effect interrupts occur every 19.3ms (1/51.6) and applying a safe 60% duty cycle results in the injector staying open for around 12ms per revolution (19.3 x 0.6).

Applying a pre-scale of eight to the timer gives interrupts every 32ms, so to arrive at the required count we simply use a proportional part of the timer. This is (12 ÷ 32) x 65,535 = 24,576.

Thus, for the maximum 12ms injection time, Timer 1 is loaded with 24,576 and the count reset to zero. As soon as it counts up to 24,576, the interrupt service routine shuts off the injector and then turns off the interrupt to prevent it from erroneously re-triggering.

This is a very useful way to control the injection time because all the injection times are calculated by the code as a proportion of the maximum, thereby making it very simple to alter the fuel mixture right across the entire range.

The VE table in the code is rudimentary and was based on data from a similar engine and then refined with results from running the engine in question. However, there's plenty of scope for the ardent experimenter to add to the VE table.

Note that if there are many more points, it would be much more efficient to set up an actual table rather than use cumbersome if/else statements. That said, despite the crudity and simplicity of the code, the engine runs surprisingly well.

Running it

Testing began on the bench and the code has liberal amounts of 'println' to indicate what is going on.

I used a square-wave signal generator to simulate the Hall sensor input signal and a frequency of about 52Hz corresponds to 3100RPM on the engine. For practicality, I replaced the solenoid with a 12V light bulb.

A correctly-running processor will flash the light bulb at the signal generator frequency and the atmospheric MAP (manifold air pressure) should match the running MAP. Applying a vacuum to the MAP sensor will then result in the running MAP dropping and the corrected timer count dropping with it. You will also see the light bulb getting dimmer, as it will be receiving shorter pulses.

If that's all good, replace the light bulb with the solenoid and listen to it run. It's quite nifty actually; it sounds quite a lot like the engine it's fuelling and varying the input frequency results in a very satisfying vroom – just like opening the throttle in your car.

Once you've finished annoying your family with this test, it's time to comment out the 'println' statements and do it all for real. If you're anything like

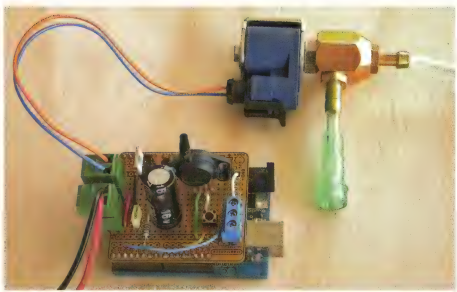


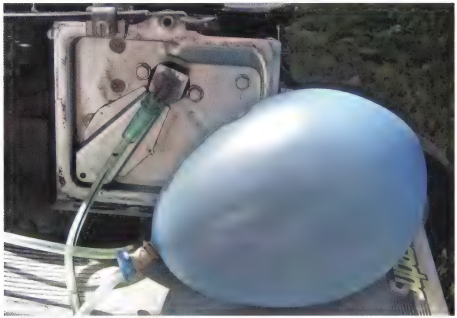
Fig.6: the electronic parts were assembled on a small piece of perforated board which plugs into the Freetronics Arduino shield. The injector solenoid is only $20 but still has a service life of 5,000,000 cycles. Its operating pressure is stated as being 0.8-2.5 bar and it operates directly from a 12V supply.

Tracking Down Parts

The solenoid and its wiring harness can be a bit hard to find. I found them, along with the propane regulator, on Aliexpress:

- Solenoid: Alexele Electric
- Matching wiring harness: LGC Gas Equipment
- Propane (LPG) regulator: BST Tool

The search engine on the Aliexpress website isn't the best I've used, so it's easiest to use Google to find the supplier, eg: "Aliexress BST Tool".



You can measure the gas flow by disconnecting the regulator from the injector and feeding it for a timed interval into a balloon. The gas volume can then be calculated by dunking the balloon into a container of the water and checking how much the water rises. This then lets you work out the volumetric efficiency (VE) and set the maximum fuelling rate.

Editor's Note

The actual volume of gas captured in the balloon will be reduced due to the elasticity of the balloon itself and the increased pressure on it when it is immersed in water.

To compensate for this, you could calculate the true gas volume by measuring the pressure inside the balloon with the MPX4250AP MAP sensor (connected via a T-piece) and using the equation: PV = nRT

assuming n, R & T are constant for this test. Data for the MAP sensor is available from www.freescale.com/files/sensors/doc/data_sheet/MPX4250A.pdf

This provides an output against pressure graph. In addition, you may want to apply compensation due to the reduced manifold air pressure in the actual engine compared to atmospheric pressure.

me, you'll want to simply plug it all in to your engine and turn knobs until it runs. This is an understandable approach but it's not as easy as it looks and to ensure success, you need to approach things with a bit more rigour.

Doing it properly first requires setting the maximum fuelling rate by adjusting the gas regulator pressure. From the previous discussions, the maximum amount of fuel is 220cc/s of LPG at 3100RPM so it follows that over four seconds (say), the injector will pass 880cc of gas.

Running the signal generator at 52Hz will simulate the engine running at 3100RPM and it is then a simple matter of capturing four seconds worth of gas in a plastic bag or balloon and then determining the volume by dunking the balloon into a large measuring container partly filled with water and checking how much the water level rises (there must be sufficient water in the container for the galloon to be fully immersed). That way, the regulator can be adjusted by trial and error.

After that, it's a matter of "giving it a whirl". First plug in the Hall sensor and make sure the solenoid clicks as you slowly pull the starter cord. That done, prime the engine and yank the cord. The engine should start and run.

A word of warning though – be sure to do all testing outdoors and always keep a fire extinguisher handy!

Wrapping up

For those unaware of it, Megasquirt is the gold standard for DIY fuel injection and the Megasquirt community has developed a fully-fledged system that is state of the art – see http://www.ms3efi.com/ A quick browse through this site will show just how much distance there is between their system and my humble Arduino model. They also offer a well-mapped path to follow for further research and development.

What's at the top of the list for future development? The answer is some sort of feedback. Until the advent of electronics, feedback consisted mainly of some guru peering at spark plugs and trying to ascertain just how well the engine was running, then adjusting the mixture by twiddling the carburettor. Nowadays, oxygen sensors are available to provide the necessary feedback on the combustion process.

If that sort of thing is in your budget, by all means fit one and use it to establish and maintain the VE table. Even fitting one for initial testing will allow you to quickly establish a baseline operating table for your particular engine – something that a club might like to get involved in.

If you're not quite so fortunate or if you have an engine that runs at a constant load for significant times (eg, in a pump), you can experiment with an exhaust temperature sensor. Simple chemistry states that the maximum flame temperature in the engine will occur when the combustion mixture is perfect, so a very cheap thermocouple sensor will give you a good indication of how well the fuel map is doing.

Just be aware that running an engine too lean will result in a lower exhaust temperature but will also result in high temperature and pressure shock waves in the combustion chamber that will rapidly destroy the engine. Also, note that the exhaust temperature decreases as the engine is loaded (the "missing" heat is going into pushing the piston and the work involved to drive the extra load!).

You could also try fitting a pot to adjust the maximum injector opening time. It's easy enough to adjust the mixture by simply changing the needle valve setting but a knob (plus perhaps an LCD readout) might be more useful.

The equations that we used don't account for any changes in air temperature, so it would also be handy to be able to tweak the mixture for maximum power to take temperature into account. This also opens the door for a subroutine to automatically compensate for ambient temperature.

Finally, the Arduino sketch software, *VE_Fuel_Injection.ino*, is available for download from the Silicon Chip website. SC

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Bass Extender Mk2

By NICHOLAS VINEN

. . . gives a big bass improvement for little outlay

Want to get deeper bass out of your loudspeakers? Who doesn't? But what if you could get more bass without spending much money? Even better – this Bass Extender can give as much as an octave more bass from your speakers! So with good quality tower speakers, you could get extended bass response down to 20Hz or below!

ALL LOUDSPEAKERS have a rapidly falling response below a certain frequency which is a basic limitation of their design. This is firstly a function of the cabinet design but is also controlled by the bass driver characteristics, such as free-air cone resonance and their Thiele-Small parameters such as Vas.

Typically, a large good-quality hifi loudspeaker system will be almost flat down to somewhere between 30Hz and 50Hz (the -3dB point or corner frequency) and will slope off below that at 24dB per octave for a vented enclosure (ie, a bass reflex system) and 12dB per octave for a sealed enclosure. Smaller speakers will have a somewhat higher corner frequency of, say, 60-80Hz.

While a frequency response extending down to around 40Hz may seem like a good figure, this means that you will miss out on the lowest bass octave. So you will miss out on the lowest fundamental notes from pianos, pipe organs, double bass, timpani, tuba – the list goes on. In fact, life probably won't be worth living.

Of course, you will still hear the harmonics of these notes when they are played but that will be but a thin shadow of what could have been. Seriously though, for a lot of music which really does explore the lower music registers, the widest possible bass response is highly desirable.

As a point of reference, the lowest note on an 88-key piano (A0) tuned for A4 at 440Hz has its fundamental at just 27.5Hz – below the -3dB point of all but the biggest and most expensive speakers available!

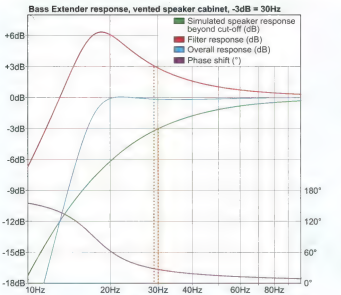


Fig.1: this plot shows the simulated vented loudspeaker response near its 30Hz -3dB point (green), the frequency response of the Bass Extender when it's active (red) and the combination of these two (blue). This shows that with the Bass Extender in place and correctly set up, the speaker's frequency response becomes much flatter in the deep bass region; in this case, from about 50Hz and below. The phase shift introduced is about 60° at 20Hz.

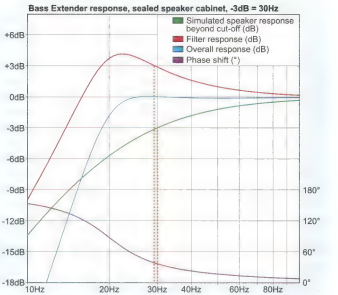


Fig.2: same plot as Fig.1 but with a simulated response for a loudspeaker in a sealed cabinet, also with a -3dB point of 30Hz. Its roll-off is not as steep and so the Bass Extender boost is more gentle. The achieved response is slightly flatter than for a vented enclosure (assuming the filter is correctly tuned) but doesn't extend to quite as low a frequency. The phase shift is slightly higher and is nearly 90° at 20Hz.

Now we know that few of our readers can afford such grandiose loudspeakers so our Bass Extender is a very worthwhile accessory and by the way, since it has a volume control, it can also double as a very wide range low-distortion stereo preamplifier.

Principle of operation

The basic idea is simple – if we know the characteristics of the low-frequency roll-off of the speakers, we can design a filter which increases signal amplitude right at the frequency where the speaker's response is dropping off, thus compensating for this loss in sensitivity at low frequencies.

That assumes that your amplifier has sufficient headroom to deliver more power at these lower frequencies. Generally, this will be the case unless some combination of the following is true: your speakers are very inefficient, your amplifier has a very low power output or you play music very loudly. If you typically run your amplifier with its volume control below the half-way point on the volume knob, it's likely that you have sufficient headroom for the Bass Extender.

There is also the issue of "frequency doubling". As we increase the drive level to a speaker operating at or below resonance (which is usually a frequency near the -3dB point), its distortion increases and ultimately, the second harmonic can overwhelm the fundamental, leading to an apparent doubling in the frequency being reproduced. But unless you have small speakers and drive them very hard, this is unlikely to be a severe problem.

Ultimately, of course, the Bass Extender cannot turn your little bookshelf loudspeakers into giant high-fidelity monsters with 15-inch bass drivers but it can certainly give you a worthwhile improvement in bass response.

By the way, because the Bass Extender can run from a 12V DC supply, it's also suitable for use in car sound systems. Mind you, you would then have to very careful about how much extra bass boost you apply!

Flattening the response

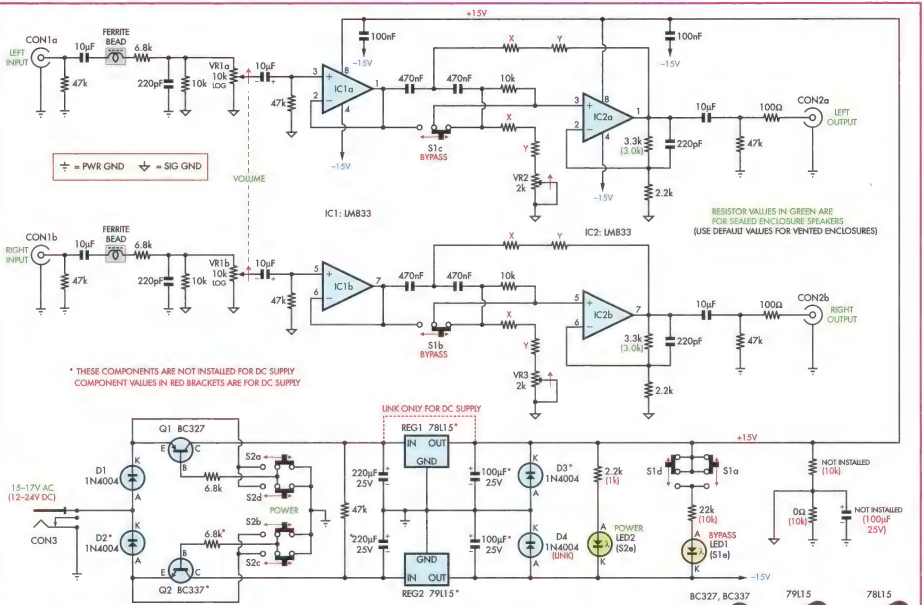
Fortunately, the bass roll-off of a loudspeaker can be modelled pretty accurately, based on two parameters: its construction (sealed or vented) and its -3dB point. As Neville Thiele pointed out in his paper "Loudspeakers In Vented Boxes", Proceedings of the IRE Australia, 1961 (reprinted in Journal of the AES, May & June 1961), sealed enclosures tend have an ultimate -12dB per octave roll-off while vented (bass reflex) speakers have an ultimate slope of -24dB per octave.

Most modern hifi speakers are vented because these tend to have a more extended bass response. If you are unsure what type of system you have, check the front and back of the speaker for ports; front ports may be hidden behind a grille. If your speakers have ports, then they are the vented type.

A -12dB roll-off is the same response as a second-order low-pass filter while -24dB matches a fourth-order low-pass filter. These are shown in green on Figs.1 & 2, with the -3dB point at 30Hz in both instances, typical of a medium-sized tower speaker.

These figures also show the response of the filter in the Bass Extender Mk2 (red) when it is tuned to compensate for these specific speaker responses. The blue curves show the compensated response of the speakers.

As you can see, the improvement in flatness is considerable, especially for vented enclosures, and is now almost completely flat to 20Hz – the small dip in the 30-50Hz region being just 0.25dB. This is inevitable, as the Bass Extender's boost does not perfectly cancel out the speaker's roll-off but it comes pretty close.



BASS EXTENDER MK2

Fig.3: the circuit includes two identical channels, each consisting of an input buffer stage (IC1a & IC1b) followed by an equal component Sallen-Key filter based on two 470nF capacitors, resistors X & Y and op amps IC2a & IC2b. Trimpots VR2 & VR3 allow the filter frequency to be adjusted.

Similarly, for the sealed enclosure, the response is now down by less than 2dB at 20Hz and is virtually flat down to about 23Hz. Either way, this is a major improvement for very little investment.

The reason the cancellation isn't quite so good for sealed enclosures is that we have to reduce the amount of boost we apply to better match their more gentle roll-off. Note that in both cases, the +3dB point of the filter in the Bass Extender is actually slightly below the -3dB point of the speaker response. This gives optimal flatness and is taken into account in the formulas we give below.

The Bass Extender Mk2 can be set up to suit sealed or vented speakers with virtually any corner frequency simply by selecting a few key resistor values, as described later. By the way, simply turning up the bass on the tone controls on an amplifier won't do the same job since that usually involves boosting frequencies well above the -3dB point of the speakers, resulting in a 'lumpy' response.

Revised circuit

This design is based on a similar circuit we published in the April 2005 issue but there are several important improvements. First, the audio performance is a lot better, partly due to the use of superior op amps but also due to more carefully chosen component values. Distortion and noise are an order of magnitude lower and the high-frequency distortion especially has been reduced.

We've also fitted it into a more attractive case and provided some externally accessible controls – a volume knob and a bypass switch. The volume knob means you can use it with an amplifier that lacks a volume control without needing a separate preamp. The bypass switch makes it easier to determine just how much effect the Bass Extender Mk2 has, as you can easily compare the sound with and without bass boost.

We have also greatly improved the headroom. With the original unit running off 12V DC and giving a 10dB peak boost, it could only just handle a 2V RMS signal without clipping. However, some CD/DVD/Blu-ray players or DACs will put out more signal than that.

By contrast, this new unit runs off a nominal 15-17V AC plugpack which means better performance and more headroom – although we have retained the option to run it off 12-24V DC, which might be required if you want to use it in a car, truck, caravan or boat.

Adjustment trimpots have been added which allow the boost frequency to be fine-tuned to match the speakers; the previous version required resistors to be changed and this wasn't much fun if you had to make multiple adjustments until you got the right effect.

Overall then, this new Bass Extender Mk2 is a much better proposition and can be added to a hifi system without degrading the sound quality.

Bass Extender Mk.2 Parts List

1 double-sided PCB, code 01112131, 148 x 80mm
1 ABS plastic instrument case, 155 x 86 x 30mm (Altronics H0377)
1 15-17VAC plugpack rated @ 100mA or more
1 set front and rear panel labels
1 10kΩ dual-gang logarithmic 9mm horizontal potentiometer (VR1)
2 2kΩ mini horizontal trimpots (VR2,VR3)
1 small knob to suit VR1
1 4PDT yellow illuminated latching pushbutton switch (Altronics S1452) (S1)
1 4PDT green illuminated latching pushbutton switch (Altronics S1451) (S2)
2 8-pin DIL IC sockets (optional)
2 stereo side-by-side PCB-mount RCA sockets (Altronics P0213)
1 PCB-mount DC socket (CON3)
2 ferrite beads
4 No.4 x 6mm self-tapping screws

Semiconductors

2 LM833 dual op amps (IC1,IC2)
1 78L15 +15V regulator (REG1)
1 79L15 -15V regulator (REG2)
1 BC327 PNP transistor (Q1)
1 BC337 NPN transistor (Q2)
4 1N4004 1A diodes (D1-D4)

Capacitors

2 220µF 25V electrolytic
2 100µF 25V electrolytic
2 10µF 50V electrolytic
4 10µF 50V non-polarised (NP) electrolytic
4 470nF MKT
2 100nF multilayer ceramic
4 220pF ceramic disc

Resistors (0.25W, 1%)

7 47kΩ	2 3.3kΩ
1 22kΩ	3 2.2kΩ
4 10kΩ	2 100Ω
4 6.8kΩ	1 0Ω

Plus 8 resistors (X, Y) selected to suit speaker roll-off; see text & Table 2

Changes For DC Power Supply

(1) Add 3 x 10kΩ and 1 x 1kΩ 0.25W 1% resistors
(2) Add 1 x 100µF 25V capacitor
(2) Delete REG1, REG2, D2-D4 and several passive components (see Fig.3)

Circuit description

The complete circuit diagram for the new Bass Extender is shown in Fig.3. CON1 is the stereo RCA input connector. The two halves of the circuit, for the left and right channel signals, are identical so we'll describe the left channel only.

A 47kΩ resistor provides ground bias/loading for the driving equipment, in case this is necessary. The signal is then AC-coupled via a 10µF non-polarised (NP) capacitor to an RC filter consisting of a 6.8kΩ series resistor with a ferrite bead slipped over one of its leads and a 220pF ceramic capacitor to ground. This forms a low-pass filter with a -3dB point of just over 100kHz so that any high-frequency signals above that do not pass on to the following stages.

Note that the 10µF AC-coupling capacitor also forms a high-pass filter in combination with its load resistance of around 10kΩ, which gives a -3dB point of 1.6Hz at the low end.

Following the RF filter, the signal passes to volume control potentiometer VR1 which is shunted by a 10kΩ resistor. The reason for this is that a following filter stage (describe later) has a gain of 2.5 and this way, with the volume control set to maximum, the overall gain through the unit is 1. That's because the 6.8kΩ RF filter resistor forms a divider in combination with the 10kΩ pot and its parallel resistor (ie, 5kΩ) and that gives a gain of approximately 0.42.

Filter Resistor Selection

To select the appropriate filter resistor values, first you need to know the -3dB low-frequency roll-off point for your speakers. Usually, this will be in the specifications (if you can find them!) but you need to be careful as the quoted frequency response isn't always measured at the -3dB points; in some cases, manufacturers use the -6dB points.

If you don't have this information, you will either have to measure it or guess. To make this measurement, you will need an adjustable-frequency sinewave generator, an amplifier and an accurate sound level meter (or a calibrated microphone and AC millivoltmeter). This type of measurement was explained in the "How To Do Your Own Loudspeaker Measurements" article in the December 2011 issue of SILICON CHIP.

Basically, what you need to do is measure the sound level at a fixed point in front of the woofer with a relatively high frequency signal being fed into the amplifier (eg, 200Hz), then reduce the frequency until you get a reading that is 3dB lower. You can then use that frequency (Fc) in the formula listed below.

If you have (or can generate) an impedance plot for the speaker, you can also use this to estimate the -3dB point. For the most common (vented) type, there will usually be two impedance peaks in the bass region. The -3dB point will be at the lowest point (dip) between these peaks.

For sealed speakers, there will be a single peak (the resonance frequency) and the -3dB point will be about 10% below this.

Failing that, use the figures in Table 1 as a rough guide. But we must emphasise that this is only a guide and the actual -3dB point will depend heavily on the driver and cabinet design and may also vary slightly between different samples of the same speaker.

Having determined the -3dB point (Fc), use the following formula to determine the required total resistance (R) for resistors X & Y:

$$\mathbf{R = T \div Fc}$$

where T = 585kΩ for vented enclosures and T = 510kΩ for sealed enclosures. It's then just a matter of determining which two series X & Y resistors add up to give a value that's close to R.

For example, if Fc = 40Hz then R = 585kΩ ÷ 40 = 14.6kΩ. In this case, you can select Y = 12kΩ and X = 2.7kΩ (close enough). Or you can use Y = 10kΩ and X = 4.7kΩ.

Note though that typical 470nF capacitors have a tolerance of ±5% at best so as long as the total is within a few hundred ohms, that's good enough. Because this is a stereo unit, you will need eight resistors in all, four of each selected value.

To save time, we have included Table 2 which shows the best resistor values to use for common -3dB points. If in doubt as to which values to use, err slightly on the side of a higher corner frequency as you can later adjust it down slightly using trimpots VR2 & VR3.

From there, the signal on the wiper of the volume pot is AC-coupled to the input of op amp IC1a (LM833) via another 10µF capacitor. This prevents IC1a's input bias current from flowing through the pot and causing a DC voltage to appear across it. While this voltage would be small, it could be enough to cause noise or 'crackling' as the pot is rotated.

IC1a buffers the signal and provides a low driving impedance for the following filter network which consists of two 470nF capacitors, two identical pairs of resistors (X & Y) and an adjustment trimpot. These resistor pairs have been used to overcome the limited range of values available in a single resistor. As far as the circuit operation is concerned, you can consider each series pair as a single resistor.

The signal at the 'output' end of the filter is now fed to pin 3 of IC2a via switch S1c, which is shown in its normal operating position. IC2a is set up as a non-inverting gain stage, with a gain of 2.5 as mentioned earlier. Its output goes both to output connector CON2a and to the junction of the two 470nF capacitors at the output of IC1a via one of the XY resistor pairs. This is what gives the filter its characteristic hump shape (see Fig.1 & Fig.2).

Trimpot VR2 allows the filter response to be tweaked without having to change component values. This is necessary because the -3dB point of the speakers you are using is unlikely to be exactly the same as the manufacturer's specification. Turning VR2 clockwise increases its resistance and shifts the filter peak lower in frequency while increasing its amplitude.

IC2a's 3.3kΩ feedback resistor is shunted with a 220pF capacitor which rolls off its frequency response well above 20kHz. This lowers its output noise and improves stability without impacting on the overall frequency response in the audio band. The output signal is AC-coupled to CON2a via a 10µF capacitor to remove any DC offset picked up in the filter. This capacitor also ensures that no damage will occur if the output is shorted to a DC supply rail.

Finally, the output is DC biased to ground using a 47kΩ resistor (in case it's floating), while a 100Ω series resistor provides some short-circuit protection for the op amp and also isolates IC2a's output from the load capacitance (eg, cable capacitance) to prevent instability.

Note that while we have specified low-noise, low-distortion LM833 op amps, others such as the NE5532 and OPA2134 are also suitable.

Bypass function

When S1c is in its alternative position, IC1's output is fed directly to IC2a's pin 3 input, bypassing the filter network entirely. This switch thus provides a bypass function and effectively allows the Bass Extender Mk2 to be disabled so that you can check whether it is having any audible effect.

S1b provides the bypass function for the righthand channel. Note that switch S1 is a 4PDT type – its other two poles (S1a & S1d) switch on its integral LED (LED1) when the bypass function is engaged. This LED is driven via a 22kΩ current limiting resistor at around 1.3mA (ie, 28V ÷ 22kΩ).

The 10kΩ resistors connected across switches S1b & S1c are shorted out during normal operation. These ensure that input pins 3 & 5 of IC2 do not go open circuit when S1 is switched, preventing loud clicks or pops from being injected into the audio signal

and making A/B comparisons with the Bass Extender enabled and disabled much easier.

A note about the use of electrolytic capacitors in the signal chain – we don't think that this is a problem and this is backed up by our measurements. However, we have made provision on the PCB for 1µF MKT capacitors to be installed instead of the 10µF electrolytics for those people who really want to do so. Besides being more linear, MKT capacitors also have a longer lifespan than electros but they cost more and are harder to get.

Power supply

The recommended power supply is a 15-17VAC plugpack. The unit can also be run off 12-24V DC with reduced headroom but the circuit is shown configured for an AC supply.

Diodes D1 & D2 form a half-wave rectifier and charge the 220µF filter capacitors to around ±20V via transistor switches Q1 & Q2. These ±20V rails are then regulated to ±15V by 3-terminal regulators REG1 and REG2, to power the op amps.

The power switching arrangement is rather unusual and consists of PNP transistor Q1, NPN transistor Q2, switches S2a/S2d & S2b/S2c and two 6.8kΩ base resistors. Basically, the two transistors are there to carry the supply current and the reason for doing it this way is that we are using a second 4PDT illuminated switch as the power switch but these are only rated to carry 50mA per contact.

While that's sufficient current to run the unit, the switch-on surge current is much higher at over 1A while the input filter capacitors charge. Paralleling the switch contacts doesn't help since inevitably, one will make contact before the others and carry the full surge current.

So Q1 & Q2 do the actual switching and this arrangement also limits the inrush current to around 450mA. The circuit works as follows: when S2 is switched to the on position (as shown in Fig.3), it connects the 6.8kΩ base resistors for Q1 & Q2 to ground. Thus, when D1 is forward-biased, Q1's emitter is at the full positive supply voltage and its base is pulled towards ground due to the current flowing through its 6.8kΩ resistor. As a result, PNP transistor Q1 switches on and so current flows from D1 to the 220µF filter capacitor across the input of REG1.

Table 1: Typical Loudspeaker Bass Roll-Off Frequencies

Woofer Size (Approx.)	Cabinet Style	Typical -3dB Point (Approx.)
>30cm (>12-inch)	Tower	25-30Hz
30cm (12-inch) or 2 x 25cm (10-inch)	Tower	28-35Hz
25cm (10-inch) or 2 x 20cm (8-inch)	Tower	35-40Hz
20cm (8-inch) or 2 x 16cm (6.5-inch)	Tower	40-45Hz
18cm (7-inch) or 2 x 13cm (5-inch)	Tower	45-55Hz
16cm (6.5-inch) or 2 x 13cm (5-inch)	Bookshelf	50-70Hz
13cm (5-inch) or 2 x 10cm (4-inch)	Bookshelf	55-80Hz
10cm (4-inch)	Bookshelf	60-100Hz

Table 2: Resistor Values For Typical -3dB Points

-3db point	Vented Y	Vented X	Sealed Y	Sealed X
28Hz	18kΩ	3kΩ	18kΩ	220Ω
30Hz	18kΩ	1.5kΩ	15kΩ	1.8kΩ
35Hz	15kΩ	1.8kΩ	12kΩ	2.7kΩ
40Hz	12kΩ	2.7kΩ	12kΩ	680Ω
45Hz	12kΩ	1kΩ	10kΩ	1.2kΩ
50Hz	10kΩ	1.8kΩ	10kΩ	220Ω
55Hz	10kΩ	560Ω	8.2kΩ	1kΩ
60Hz	8.2kΩ	1.5Ω	8.2kΩ	270Ω
70Hz	8.2kΩ	150Ω	6.8kΩ	470Ω
80Hz	6.8kΩ	470Ω	4.7kΩ	1.5kΩ
90Hz	4.7kΩ	1.8kΩ	4.7kΩ	1kΩ
100Hz	4.7kΩ	1.2kΩ	4.7kΩ	330Ω

Q2 operates in similar fashion. When D2 is forward biased, Q2's emitter is pulled to the negative supply rail and so this NPN transistor turns on and current now flows through D2's anode and charges the 220µF filter capacitor at the input of REG2.

In operation, the 6.8kΩ resistors limit the transistor base currents to around 20V ÷ 6.8kΩ = 3mA. Since a BC327/337 has a current gain (hFE) of about 150 under that condition, this means that the collector currents are limited to around 3mA x 150 = 450mA.

If power switch S2 is in the alternative position (ie, off), each 6.8kΩ base resistor is connected back to the emitter of its respective transistor. This effectively 'shorts' out the base/emitter junctions and switches both transistors off. In this condition, the only current drawn from the supply is the leakage current through Q1 & Q2 which is very low (typically <100nA).

The 47kΩ resistor between the two regulator inputs provides a discharge path and prevents this leakage current from (very slowly) charging the input capacitors.

The power LED (LED2, inside S2) is connected in series with a 2.2kΩ current-limiting resistor across the regulator outputs. Diodes D3 & D4 prevent the regulator outputs from becoming reverse-biased by more than about 0.5V during power-up or power-down.

Note that while you may be able to get away with using a cheaper and smaller 12VAC plugpack rather than the 15-17VAC plugpack specified, it's a bit marginal. If using a 12VAC plugpack, you would want to check that its actual output under light load is at least 13VAC (and ideally higher) in order to prevent the regulators from entering drop-out. Having said that, even if they do, the performance should still be quite acceptable.

DC supply

Note that one 10kΩ resistor and one

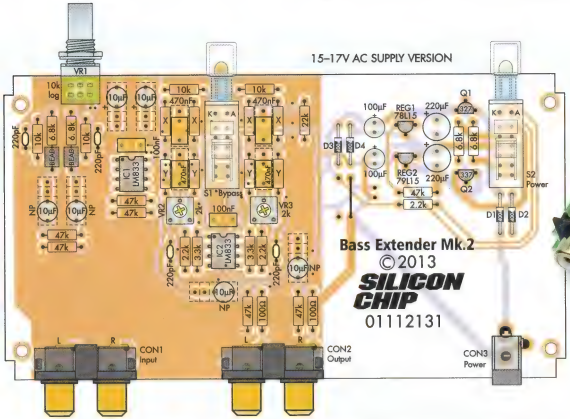


Fig.4: follow this layout diagram to build the PCB if you are going to power the unit from a 15-17V AC plugpack. Note that there's provision for the PCB to accept 1µF MKT capacitors instead of the 10µF electrolytics if you don't want to use electrolytics in the signal chain (and different MKT capacitor sizes are catered for). Resistors X & Y are selected from Table 2, as described in the "Filter Resistor Selection" panel.

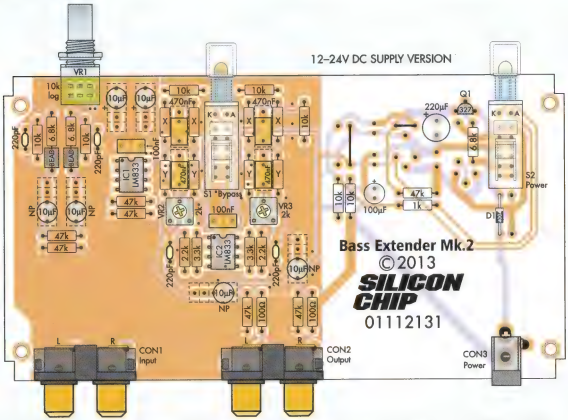


Fig.5: this is the layout diagram to follow if you intend running the unit from a 12-24V DC supply. The differences between this and the AC-supply version of Fig.4 mainly involve the power supply components at top right plus the current limiting resistors for LED1 & LED2.

100µF capacitor (ie, across the 15V rail) are not installed when using an AC plugpack. In addition, one resistor is specified as 0Ω.

For operation from a 12-24V DC plugpack (higher being better), the components marked in red on the circuit must be changed. First, D4 is replaced with a wire link, so that the negative supply rail of the op amps is now connected to the power supply ground. Second, the LED current-limiting resistors are reduced to give sufficient brightness with the lower operating voltage. And third, we need to adjust the DC input bias for all four op amps so that it will be at half supply; eg, with an 18V supply, it must be at 9V.

That's done by fitting two 10kΩ resistors across the supply rail as a voltage divider, along with a 100µF filter capacitor to filter any supply noise. This capacitor is critical because without it, any ripple or noise from the plugpack supply would get into the audio path. Modern plugpacks are switchmode devices, so there are often audible harmonics present.

Finally, when operating from DC, REG1 is linked out since this gives the op amps maximum headroom and they should have sufficient supply ripple rejection to run from an unregulated DC rail.

Construction

All the parts for the Bass Extender Mk2 are mounted on a PCB coded 01112131 and measuring 148 x 80mm. This fits neatly into an ABS plastic instrument case measuring 155 x 86 x 30mm and is secured to the integral stand-offs in the case using self-tapping screws.

Figs.4 & 5 show the parts layout on the PCB. Follow Fig.4 if you are building the AC-powered version. Alternatively, follow Fig.5 if building the DC-powered version.

Start the assembly by fitting all the resistors, including the eight selected for X and Y (see "Filter Resistor Selection" panel and Table 2). Note that the ferrite beads should be slipped over the two 6.8kΩ resistor leads before soldering them in place. It's a good idea to check each resistor value using a DMM before fitting it.

Follow with the diode(s) and then the two IC sockets. Alternatively, if you aren't using sockets, solder the op amp ICs directly to the PCB. Note that in either case, the notches/dots at one end of the sockets/ICs must go towards the top of the PCB.

The two trimpots can go in next, followed by the transistors and regulators (if fitted). Note that the transistors and regulators all look the same so be sure to check their type numbers carefully before installing them. You may need to crank their leads out slightly to fit the PCB pads.

The six ceramic capacitors are next on the list, followed by the two slide switches (S1 & S2). Check that the latter are sitting flush against the PCB before soldering their pins (it's a good idea to re-check this after lightly soldering the first two pins). The DC socket, MKT capacitors and electrolytic capacitors can then all go in.

Take care to ensure that the polarised electros are all orientated correctly. The four non-polarised (NP) 10µF electrolytics can go in either way around.

The PCB assembly can now be completed by fitting the volume pot and the stereo RCA sockets. Before fitting the latter, they need to be modified. As supplied, they are too tall to fit

Table 4: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
470nF	0.47µF	470n	474
100nF	0.1µF	100n	104
220pF	NA	220p	221

Table 3: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	7	47kΩ	yellow violet orange brown	yellow violet black red brown
❑	1	22kΩ	brown black orange brown	brown black black red brown
❑	4	10kΩ	brown black orange brown	brown black black red brown
❑	4	6.8kΩ	blue grey red brown	blue grey black brown brown
❑	2	3.3kΩ	orange orange red brown	orange orange black brown brown
❑	3	2.2kΩ	red red red brown	red red black brown brown
❑	2	100Ω	brown black brown brown	brown black black black brown
❑	1	0Ω	single black stripe	single black stripe

Left: the PCB assembly is mounted on the lid of the case and is secured to integral stand-offs using four self-tapping screws.

Right: rear view of the completed unit. It's installed between the preamp and the amplifier.

into the case so it's necessary to cut off the upper projection with the central screw hole. This can be done using a rotary cutting tool or a hacksaw but make sure you don't damage the lower plastic housing. You can then fit the sockets in place, ensuring that they are pushed all the way down and are parallel with the edge of the PCB.

The plastic tabs on either side of the sockets fit into matching holes in the PCB to help hold them in place.

Having done that, separate the case halves by removing the front and rear panels, then fasten the PCB assembly to the top half using four No.4 x 6mm self-tapping screws. This means that when the case is later assembled, the PCB hangs upside down off the lid.

Testing

If you fitted IC sockets, leave the op amps out of circuit for the time being. Now for some initial checks: first, make sure that both switches are off (push them until they pop out), then connect the plugpack supply and switch on.

Next, use a DMM to check the DC voltage between pins 4 & 8 of one of the IC sockets (or between pin 4 & 8 of one of the ICs); you should get a reading that's very close to 0V (ie, with power switch S2 off).

Now push the power switch and check that both LEDs illuminate. The

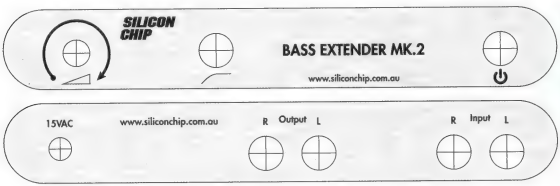


Fig.6: these two artworks can be copied and used as drilling templates for the front & rear panels. They can also be downloaded as a PDF file from the SILICON CHIP website.

voltage between pins 4 & 8 of the IC socket (or IC) should now measure 30V DC for an AC supply, or about the same as the plugpack output voltage if you are using a DC supply.

Next, if using an AC supply, connect the black probe to pin 3 of IC1 and measure the voltage at pin 8 (+15V) and pin 4 (-15V). For a DC supply, check the voltage between pins 3 & 4 of IC1; you should get a reading almost exactly half that between pins 8 & 4.

Assuming this all checks out OK, press S1 (Bypass) in and check that its LED switches off, then switch off and install the two op amp ICs in their sockets. That done, connect the unit between a signal source and your amplifier (turn the volume down first), switch on and verify that undistorted audio is passing through the unit, for both channels.

You can now check whether the unit is doing its job, ie, extending the bass response without introducing any dips or peaks in that region. If you have a speaker measurement set-up, as described in the December 2011 issue, then you can run this to plot the frequency response in the 20-200Hz region to check this. If not, you will have to do it by ear but that's far less precise.

The simplest test would be to run a sinewave frequency sweep and listen for any obvious peaks or dips. If there is a peak present that goes away with the Bass Extender's defeat switch activated, that suggests that you have the roll-off frequency set too high. In that case, you can turn trimpots VR2 & VR3 slightly clockwise to decrease the frequency of the bass boost and re-test the set-up. If necessary, you can repeat this procedure until the peak disappears.

If adjusting VR2/VR3 fails to remove the peak (even when they are set fully clockwise), then you will have to change resistors Y and/or X in order to decrease the roll-over frequency further. Note that it's easier to do this adjustment one channel at a time.

Conversely, if there's a dip in the response, that suggests that the roll-over frequency is too low and if VR2/VR3 are set at minimum (fully anti-clockwise), the only option then is to change resistors Y and/or X.

Finishing off

Once you are happy with the results, you can prepare the front and rear panels. The labels shown in Fig.6 can be copied and used as drilling templates (or they can be downloaded in PDF format from www.siliconchip.com.au – free to online subscribers). It's simply a matter of accurately drilling the three front panel holes and the five rear panel holes. That's best done by first drilling small holes with a pilot drill (say 2-3mm) and then carefully enlarging them with a tapered reamer.

Once drilling is complete, de-burr the holes and then attach the panel labels (the labels can be printed onto photographic paper and attached using silicone). The case lid can then be fitted in position, the front and rear panels snapped on and the knob pushed onto the pot shaft.

You can now hook the unit up permanently. It should ideally go between your input selector/preamplifier and power amplifier. If you have an all-in-one unit, check if it has preamp-out/preamp-in connections and if so, use those. Otherwise you will need to connect it between your most commonly used signal source (eg, CD player) and the amplifier.

Finally, it may be possible to build the unit permanently into your stereo amplifier and run it from a 15-17VAC secondary tap on the mains transformer. SC

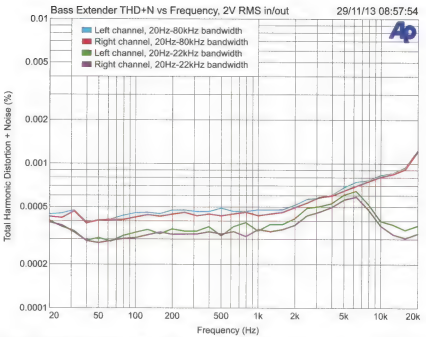


Fig.7: total harmonic distortion across the audible frequency range with the unit operating in typical conditions. This shows that the unit is suitable for use in a hifi system, with distortion below 0.001% over virtually the entire frequency range (even with a bandwidth of 80kHz, which is used to show the slight rise of distortion with frequency). With the bandwidth limited to a more realistic 20kHz, distortion never rises above 0.00065%.

Features & Specifications

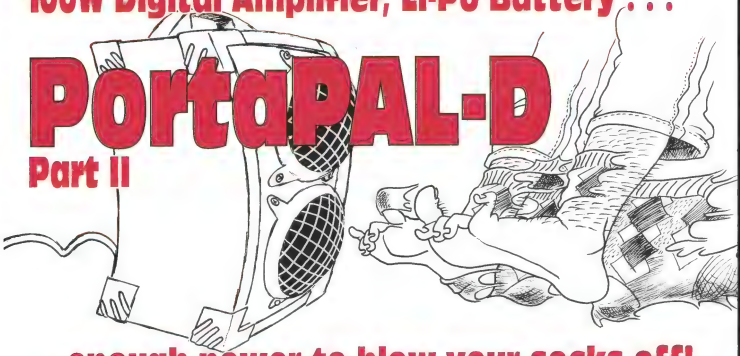
Power supply	15-17VAC or 12-24V DC @ <100mA
Signal handling	3.88V RMS (+14dBu) (AC supply)
Frequency response (bypass mode)	20Hz-20kHz, +0,-0.06dB
Boost corner frequency	+3dB at 20-100Hz
Peak boost	approximately +10dB
Suitable speaker types	bass reflex, sealed
Gain adjustment	0-1
Total harmonic distortion	<0.0005% up to 1kHz (see Fig.7)
Signal-to-noise ratio	-113dB, unweighted

Note: measurements taken with 20Hz-20kHz bandwidth, 2V RMS signal and gain = 1.

100W Digital Amplifier, Li-Po Battery . . .

PortaPAL-D

Part II



. . . enough power to blow your socks off!

In the second part of our new go-anywhere Portable PA system, we put together all the electronics. There's a lot to it, but we've separated out each section to simplify matters. So let's get stuck into it!

As described last month, we use the CLASSiC-D Amplifier module and its matching speaker protector from the November and December 2012 issues, along with the DC-DC Converter from May 2013 which allows the CLASSiC-D amplifier to run from a 12V supply.

Both the CLASSiC-D Amplifier and the speaker protector need to be set up for the ±35V supply option as detailed in their construction. But more on this later.

Firstly, we will describe the building of the main PortaPAL-D mixer and input PCBs. There are three PCBs for these: the largest is the main PCB (Mixer and power supervision) coded 01111131 and measuring 212 x 100mm; the Guitar and Line Input/Output PCB is coded 01111132 and measures 109 x 35mm and finally the Microphone input PCB coded 01111133 and measuring 64 x 73mm.

Check each PCB carefully for any problems such as undrilled or incorrectly sized holes and for poor etching. Typically, PCBs supplied in kits or from the SILICON CHIP shop are excellent quality and should not require any repairs.

Microphone input PCB

We'll start with the smallest PCB. Follow the overlay diagram in Fig.7. The resistors are installed first, but note that the four 1kΩ resistors each have a ferrite bead placed over the lead at one end. As well as checking each resistor against the colour code shown last month, measure each one with a multimeter to verify its value.

IC1 can be directly soldered onto the PCB or mounted using an IC socket. Either way, make sure it is oriented correctly. Similarly, electrolytic capacitors (which can be installed next) are also polarised. For the smaller capacitors, where the value is not printed on them, the codes were shown in the capacitor codes table last month.

by John Clarke

CON3 comprises a 6-way right-angle pin header. Along the longer side of the header is a thin plastic backing piece behind the pins. This needs to be cut off (using side cutters) to allow the pins to plug into the single in-line socket on the main PCB.

Two PCB-mount XLR female connectors (CON1 & CON2) are soldered onto the PCB. The connectors are ultimately secured to the front panel with self tapping screws. The central hole at the top of the PCB under the XLR connectors is for a chassis mount earth point.

This can be a 6.4mm spade terminal or a crimp eyelet that mounts on the rear of the PCB using an M3 screw and nut with star washers top and bottom of the PCB to ensure a good earth connection to the PCB copper.

Guitar and line input and output PCB

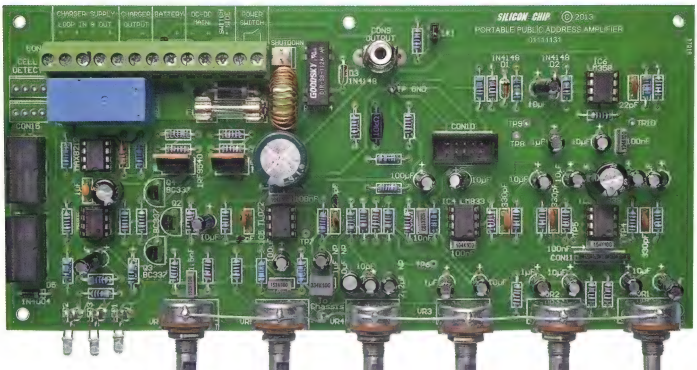
Like the first board, construction can begin with all resistors and capacitors. Again, take care with polarity of the electrolytic capacitors. Like IC1, IC2 can be either directly mounted onto the PCB or using a socket. Be sure to orient the socket and IC correctly.

The 6.35mm jack sockets (CON4 & CON7) as well as the stereo RCA sockets (CON5 & CON6) mount as far down onto the PCB as they can go before soldering the pins. Finally, insert and solder in the 10-way IDC connector with the notched section toward CON6.

Mixer and power supervision PCB

This PCB overlay is shown in Fig.8. Construction follows the same pattern: resistors first, followed by the diodes. There are three types used; 1N4148s, a 1N4004 and a 1N5404. Make sure these are inserted in their correct positions and with the correct orientation.

Two PC stakes are used on the PC board. One is for TP GND and the other for the GND pin between VR4 and VR5. The remaining test points


SILICON CHIP
PORTABLE PUBLIC ADDRESS AMPLIFIER
CHARGER SUPPLY
BATTERY
POWER SWITCH
CON5
CON10
CON14
CON15
CON9
CON1
CON12
CON11
IC1 LM833
IC2 LM833
IC3 LM386
IC4 LM386
IC5 LM386
IC6 LM358
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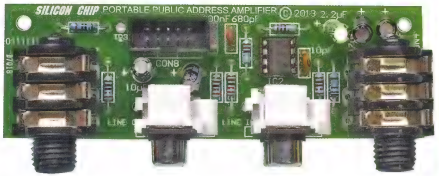
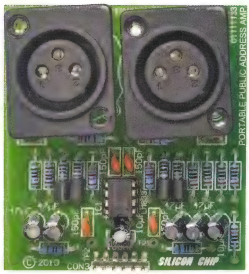




At left is the main PCB (mixer and power supervision) shown slightly less than full size. Note the wire soldered to all pot bodies thence to the PCB. Above is the guitar and line input PCB (left), shown full size, and similarly the microphone input PCB at right. The XLR (microphone) sockets on this board look slightly skewiff . . . because they are! We didn't have any PCB mounting sockets on hand and the photographer was waiting! Your board, using the right sockets, should look perfect.

not install the horizontal RCA socket (the one that protrudes past the edge of the PCB) – just install the vertical mount RCA socket.

Heatsink drilling is also changed to include the 50 degrees C thermostat that is secured to the right hand side of the heatsink (above the V_{CC} and COM PC stakes). The thermostat is attached using M3 screws that are screwed into M3 tapped holes in the heatsink. The thermostat is mounted as high on the heatsink as possible without the thermostat body showing above the heatsink edge. The screw holes are positioned to pass though the heatsink and between the fins.

The ground lift jumper shunt is installed for the PortaPAL-D. This ensures the minimum noise is produced.

Speaker protector

The CLASSiC-D Amplifier's Speaker Protector should be constructed as shown in Fig.23 of the December 2012 issue, using the values shown for use with a 35V supply. The 47µF delay capacitor is changed in value to 10µF. Being the only capacitor on the PCB, it is easy to locate. The capacitance change improves the overall response of the PortaPAL-D when switching from standby to producing an output.

DC-DC Converter

Build the DC-DC Converter as it is shown in the May 2013 issue except for two changes. First, change the 13kΩ resistor connecting to the anode of D3 to 10kΩ. On the PCB, this is located between ZD1 and diode D3. This resistance change reduces the low battery shutdown voltage of the DC-DC Converter to 10V. This is more suiting to the LiPO battery used in the PortaPAL-D. The second change is not to connect the earth wire from the TP GND terminal to the chassis. Instead, the DC-DC Converter case is earthed directly to the PortaPAL-D chassis once it is secured in place.

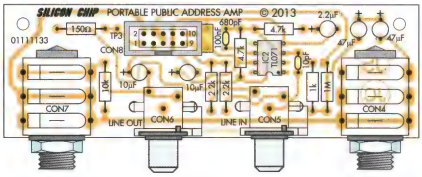
Chassis

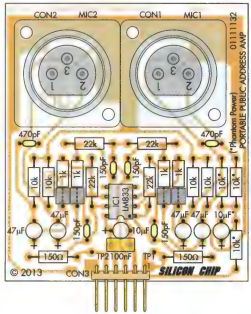
As shown in our photos, the PortaPAL-D is built on two L-shaped aluminium chassis panels which screw together into an open-ended box. Each of these panels is bent from a 300 x 300mm x 1mm aluminium sheet.

Fig.10 and 11 show the folding and drill layout for these two panels which can be made using basic hand tools. Some of the holes are countersunk, as shown in Fig.11.

For the cutouts, we drilled a series of holes around the inside perimeter of the cutout, then filed the it to shape.

In the absence of a metal bender, the 90° bends can be folded over the edge of a bench with the sheeting held in place with a timber block and clamps. A rubber mallet can be used to finish folding the aluminium flat along the bend crease.





Figs.6&7: component overlays for the guitar and line input PCB (above) and the microphone input PCB (right). The two boards mate to the main PCB via CON8 to CON10 and CON3 to CON11, respectively,

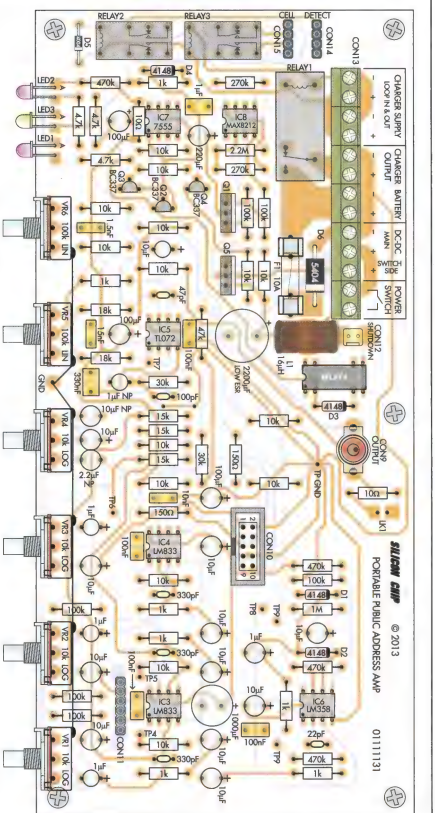


Fig.8: this board contains all of the mixing and audio signal control circuitry before it is passed off to the CLASSiC-D amplifier module from CON9. But it also contains the important power monitoring and processing circuitry to prevent damage to the Li-Po battery. These batteries, while light and powerful, are not quite as forgiving as other types if mishandled in the charging/discharging department.

After bending, you will have two L-shaped chassis pieces. One includes the front panel and onto this attaches the mixer, microphone and guitar PCBs and the charger. The second piece is for mounting the CLASSiC-D amplifier, the speaker protector, the DC-DC Converter, the fan and the battery.

We attached two small cabinet handles 45mm long x 15mm high x 6mm wide to the edges of the front panel. This is to allow the panel to be more easily removed from the loudspeaker cabinet. Our handles were fashioned by cutting the corner pillar sections from the base of a UB5 blue translucent box but small drawer or cabinet handles, available from any hardware store, would be even better.

Brackets

Four Aluminium brackets are required. These are made using 12 x 3mm aluminium bar.

Both the charger bracket and battery bracket have a heatshrink tubing covering to protect the charger and battery from direct contact with the aluminium that may otherwise short to the battery or damage the charger case.

Fig.12 shows the 110mm-long charger bracket. 3mm diameter holes are drilled 104mm apart with one hole being countersunk for the right-angle bracket. The aluminium is covered with a 95mm length of 10mm diameter heatshrink tubing, shrunk down using a heat gun.

Fig.12 also shows how the Charger Bracket is used with one end having two 12mm lengths of M3 tapped spacers supported with an M3 x 20mm screw. This is held in the front panel with an M3 x 10mm screw. At the other end of the bracket, a right angle bracket is attached using a countersunk screw. The right angle section then mounts to the horizontal panel of the L-shaped panel that also holds the CLASSiC-D amplifier.

Fig.13 shows the two frame brackets. These support the chassis junction between the top two mounting holes of the CLASSiC-D amplifier PCB and two of the main mixer PCB mountings that are directly opposite from the amplifier. With good fortune, the same spacings are between the standoffs in the CLASSiC-D amplifier and the main mixer. As shown in Fig.13, the brackets are 65mm long with 3mm diameter holes 55mm apart with a right angle bracket attached at one end.

For the battery bracket, the arrangement is shown in Fig.14. The bracket is 83mm long with holes 73mm apart. The bracket is covered with an 87mm long length of 10mm heatshrink tubing. Two stacked 12mm, M3 tapped spacers are held at each end with M3 x 20mm screws. The bracket holds the battery in place with M3 countersunk screws into the CLASSiC-D chassis along the horizontal panel.

Chassis assembly

For the front panel L-shaped chassis section, check that the mixer PCB fits correctly with the potentiometer and LEDs fitting into their allocated holes. The Preamp mounts on 15mm tapped standoffs that are attached using six M3 x 6mm screws. These are only used along the rear of the PCB. The potentiometers support the PCB at the front.

We placed a potentiometer nut on each potentiometer before securing with another nut on the outside of the panel. This spaces the PCB back a little from the front panel.

Also check that the microphone input PCB and the Guitar and line input PCBs fit correctly onto the front panel. The microphone PCB is plugged into the 6-way socket on the main mixer PCB and the XLR sockets fit into the holes in the panel. The PCB is supported in place using M3 screws or self tapping screws into the XLR socket mounts.

The guitar PCB is held in place via the 6.35mm jack sockets that are secured to the panel with a nut. The RCA sockets are secured with self tapping screws. Check also that the charger fits into its cut out.

Front panel

Once these fit correctly, the PCBs should be removed so that the front panel label can be attached. The front panel can be printed out from the file on www.siliconchip.com.au. We used A4 photo paper and adhered the printout to the panel with Silicone sealant. The panel was then sprayed with a

Here are the completed PortaPAL-D PCBs mounted on their respective L-shaped panels. All the wiring remains connected (to make it easier to follow) with the exception of the main DC connector from the LiPo battery (the red and black cables which go off the bottom of the page) and the 5-wire balance connector which connects to each of the cells in the battery (the loose white plug and socket). Compare this to the layout diagram overleaf. With the two panels folded and screwed together, the module is complete – all it needs is to be inserted into its possie in the speaker box and the two speakers connected.

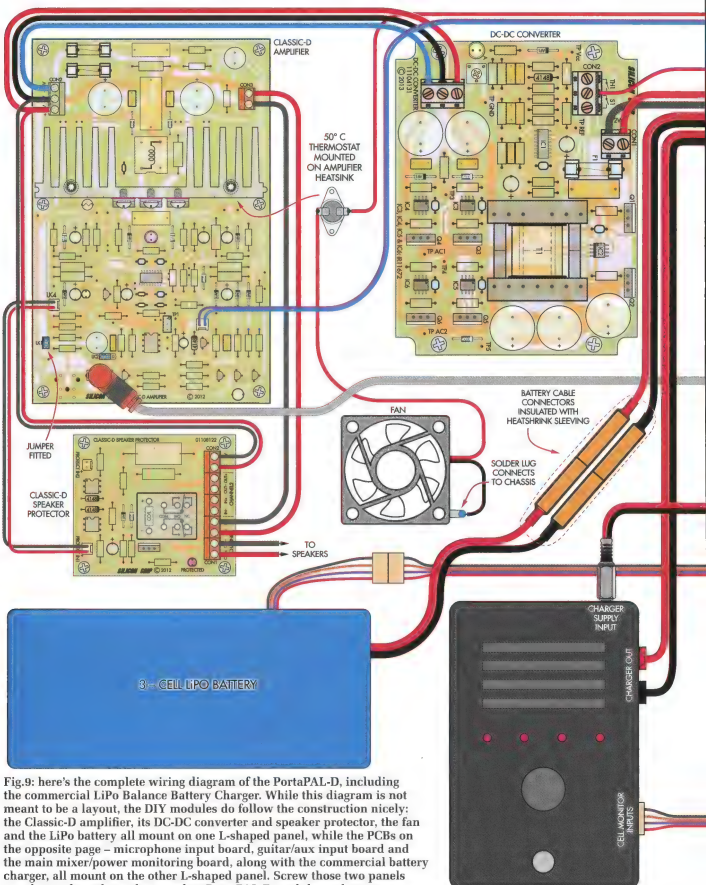
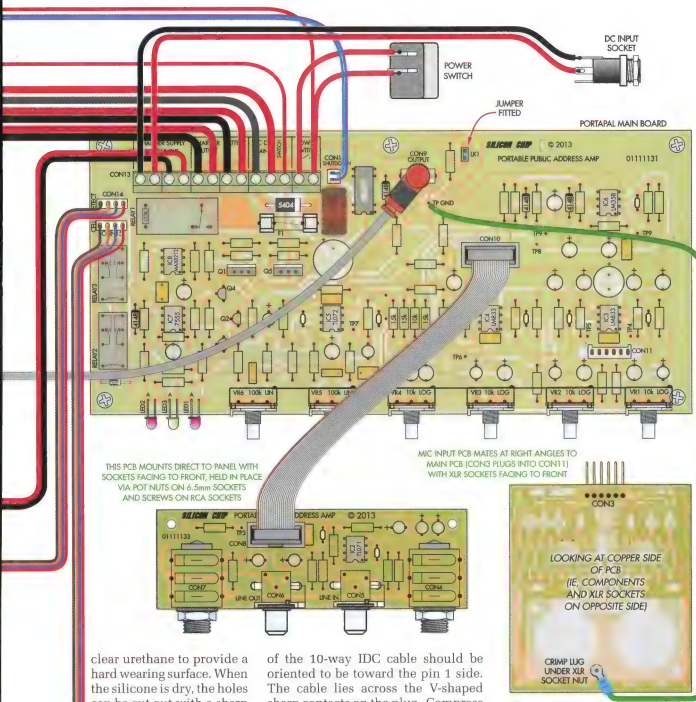


Fig.9: here's the complete wiring diagram of the PortaPAL-D, including the commercial LiPo Balance Battery Charger. While this diagram is not meant to be a layout, the DIY modules do follow the construction nicely: the Classic-D amplifier, its DC-DC converter and speaker protector, the fan and the LiPo battery all mount on one L-shaped panel, while the PCBs on the opposite page – microphone input board, guitar/aux input board and the main mixer/power monitoring board, along with the commercial battery charger, all mount on the other L-shaped panel. Screw those two panels together and you have the complete PortaPAL-D module as shown on page 31, ready to mount in the speaker box. Did we forget to mention you have to build that too?


DC INPUT SOCKET
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JUMPER FITTED
PORTAPAL MAIN BOARD
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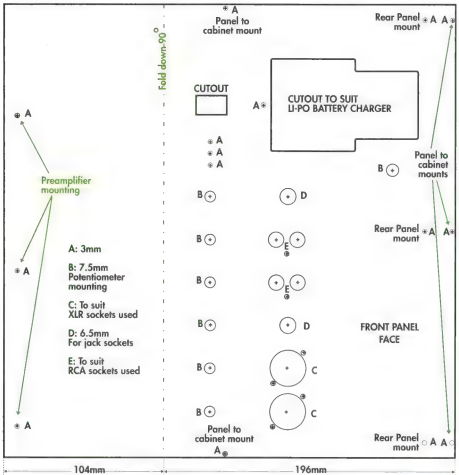
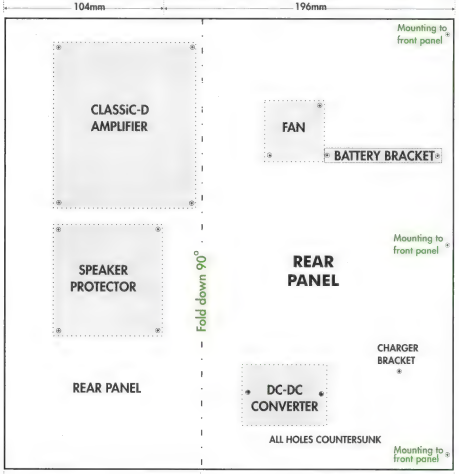
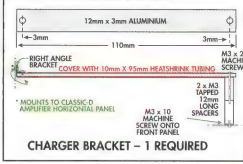




Figs. 10&11 (left) show the sizes and drilling details for the two panels. These are reproduced at 40% life size. Figs. 12,13&14 (below and right) are details of the four brackets required. Much larger versions of these drawings, with more detail can be downloaded from www.siliconchip.com.au



CHARGER BRACKET – 1 REQUIRED

from each other using two M3 x 10mm countersunk screws on the underside of the chassis. Two M3 x 15mm screws are used to secure the fan to the spacers.

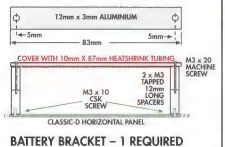
The DC-DC Converter mounts onto the chassis using two M3 x 6mm countersunk screws. Position the DC-DC Converter box over the two mounting holes and mark out on the box where the holes are to be drilled. Drill the two holes at 2.5mm (3/32") in the box before tapping the thread with an M3 tap. Be sure to clean out any metal shavings from within the DC-DC Converter box.

The battery is secured in place using the battery clamp. Use M3 x 20mm screws to secure the two 12mm spacers to the bracket and M3 x 10mm countersunk screws to attach the spacers to the panel.

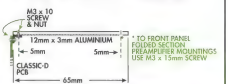
Wiring

Before assembling the two L-shaped chassis panels together, some of the wiring can be completed. For the CLASSiC-D amplifier chassis, that means that wiring can be done between the DC-DC Converter +/- 35V supply outputs and the CLASSiC-D amplifier and speaker protector plus interconnecting wires between the amplifier and the speaker protector. Fig.13 shows the wiring diagram.

Wires connecting to the power input of the CLASSiC-D amplifier are held against the heatsink with a "P" clamp. This helps to keep the wires away from internal cleats when the chassis is inserted in the speaker box. Most wiring is done using 7.5A rated wire. Typically the 0V wiring would be in black, positive wiring in red and earthing wiring in green. Using colour



BATTERY BRACKET – 1 REQUIRED



FRAME BRACKET – 2 REQUIRED

conventions helps to ensure the correct power polarity is connected.

The protect lead, comprising a 2-way lead with 2-pin header sockets on each end, plugs into the Protect IN1 plug on the speaker protector and LK4 on the CLASSiC-D amplifier.

Wiring of the fan to the thermostat can also be done. Fan wiring involves securing a solder lug under one of the spacer supports against the chassis and soldering the black fan lead to this. The red positive lead from the fan connects to the thermostat. The second thermostat terminal is the positive supply lead for the fan. This and the supply leads for the DC-DC Converter can be prepared ready to connect to the main mixer PCB.

Two other leads can also be prepared. One is the 150mm length of single core screened cable that has an RCA line plug connected to each end: one end is plugged into the CLASSiC-D amplifier input RCA socket while the other end is ready for connection to the main mixer PCB RCA outlet. The second is a 270mm length of twin figure-8 light gauge wire with a 2-pin header socket on each end. This lead connects to the LK3 protect header on the CLASSiC-D amplifier, while the other end connects to the main mixer PCB at the shutdown connector CON12.

Front panel chassis wiring is mainly for the charger and battery plus the interconnecting wires to the other CLASSiC-D chassis. Wires connect from the power switch itself to the power switch terminals on the mixer PCB. For the charger, a 2.5mm DC line plug connects to the charger supply input on the charger and the wires connect charger supply out terminals on the main mixer PCB.

The charger supply input terminals on the mixer PCB connect to the 2.5mm DC panel connector. Charger output terminals on the mixer PCB connect to the charger output on the charger itself using right angle banana plugs. Red is for positive and black for the negative plug.

Battery supply terminals on the mixer PCB connect to leads that are terminated into Polymax 5.5mm Gold Connectors. The negative lead is terminated into the socket and the positive lead is terminated into the plug. These are designed to plug into the plug and socket leads on the battery. Note that it is important to place heatshrink tubing over the plug and socket so that when connected to the battery terminals, there is no exposed metal. Note that the leads as supplied with the battery have their terminals excessively covered in protective heatshrink tubing. It will be necessary to remove the excess tubing covering the plug portion of the negative lead plug and directly at the end of the red positive lead socket to expose the socket. You can connect up the 4-way cell sensing plug and socket to the battery and charger but do not connect the battery terminals yet.

The LiPo Battery Charger

The battery charger we used for this project is a commercial unit which we mounted inside the PortaPAL-D case.

We can already hear the question: "Why buy a commercial charger when you could have designed one and built it in?"

The answer is, quite simply, that we couldn't have hoped to build a battery charger for anything like the price of the HobbyKing TE4 Balance Charger (www.hobbyking.com). At time of writing, it sold for $AU13.12.

This particular charger handles from 1-4 Lithium Polymer cells with an auto charge current of between 100mA and 4500mA from a DC input of 11-15V. Furthermore, as its name suggests, it automatically balances the charge on each of the cells (which accounts for the direct connection to those cells).

The lower photo shows the output connectors (large red and black terminals) along with the balance terminals for 2, 3 or 4 Lithium Polymer cells.

There are two earthing wires. One is from the battery minus terminal on the main mixer PCB to the chassis. The second is from the microphone input PCB that connects to the TP GND PC stake on the main mixer PCB.

The two L-shaped chassis sections can now be connected together. The base of the CLASSiC-D amplifier chassis piece connects to the front panel using right angle brackets. The CLASSiC-D amplifier PCB's top mounting holes are attached to the frame brackets using right angle brackets. The opposite end of the frame brackets attach to the same screws that secure the main mixer PCB to its chassis.

Connect the supply and switch wiring to the DC-DC Converter and plug the RCA plug lead into the RCA output on the mixer PCB. Also connect the 2-pin header socket lead to the CON12 shutdown header.

NEXT MONTH:

We'll build the PortaPAL-D box, cover it in speaker carpet, fit the speakers and then fit the PortaPAL-D module to the box to finish it off. In the meantime, you have plenty of work to do! SC

SERVICEMAN'S LOG

A typical day in my working life

Dave Thompson*

It would be easy to get the impression from this column that most service work involves clever sleuthing to solve tricky problems. But that's really not the case; instead the vast majority of service work is fairly routine. Here's a typical day in my working life . . .

Items Covered This Month

- A typical day in my working life
- Solat hot water fault
- Samsung Syncmaster 740N monitor

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Email: dave@pcanytime.co.nz

Every serviceman has regular jobs that really are the foundation of his business. Basically, they are the "bread and butter" jobs that he deals with almost every day – jobs he knows inside and out and may even be sick and tired of doing. However, it's this type of work that keeps the kids in designer sneakers and the fridge well-stocked with boutique beverages.

In many cases, this routine (and often very basic) work doesn't require specialist tools or trade-specific hardware. However, it can often require hard-won knowledge and years of experience to get the job done.

Of course, service work can vary greatly and while many routine tasks are often still interesting to SILICON CHIP readers, most of the servicemen who contribute to this column tend to write about their more unusual jobs. But most service work simply isn't like that; instead, it's all rather routine. It's just that you don't get to hear it.

Recently, however, a reader wrote in suggesting I talk about some of the bread-and-butter work in my trade so this month I thought I'd walk you through an average day in my working life as a computer repairman. What follows is a typical day in my computer repair workshop.

Up with the sparrows

The first thing I do when I walk into my workshop at around 7.30 in the morning (an hour before I officially open) is turn all the workshop computers on. There is great debate over whether to turn workstations off when not in use and no doubt this will rage on as long as there are computers as we know them. For what it's worth, I shut our non-essential workshop computers down overnight; not only do they use no power when they are switched off but there is a lot less chance of fire or accidental damage (eg, due to a power surge). The last thing I want is to be calling clients and informing them that their pride-and-joy has melted into the workbench!

What's more, in Christchurch, the possibility of earthquakes is always in the back of my mind. We haven't had a really nasty shake for quite a while (at least one capable of toppling computers off workbenches) but there is always the risk of one happening. In short, the less machines powered up and sitting on workbenches the better.

Of course, it can always be argued that a computer on standby uses sod-all power anyway but to my engineering-evolved way of thinking, if something isn't running it isn't wearing out and nor can it cause other problems. As a result, all my workstations, except those in use recovering files or copying data, are switched off as part of our end-of-day routine.

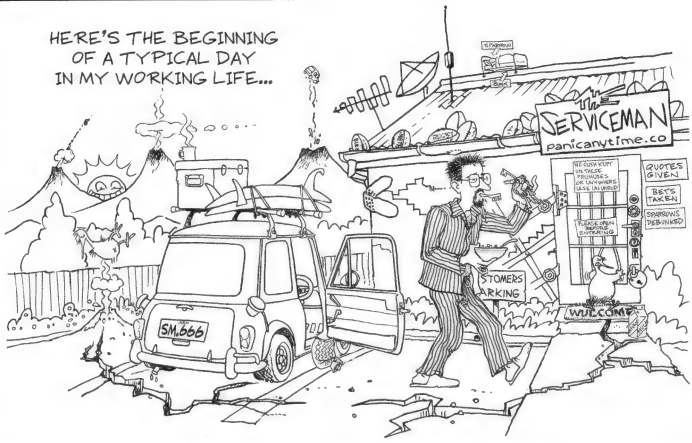
By contrast, our company file server runs all the time but uses hardware designed for continuous use and is also well-protected by an industrial-strength uninterruptible power supply (UPS). This ensures we don't have any worries with it, even with the sometimes appalling quality of the mains power we are living with in post-quake Christchurch.

Once all the computers have fired up, I check for messages; there might be a phone message or two and increasingly these days, emails sent from the contact form on our website. Phone messages left after-hours are often hang-ups as callers decline to leave a message; most people calling a computer repair outfit want to talk to someone then and there, usually fishing for free advice on how to fix a problem they're having. If nobody answers they simply hang up and try the next number in the phone book.

If someone does leave a message, I have text alerts set so I get notified and can call in and process it. If the call warrants an immediate response, I call then and there; if not, I make a note and call during working hours the following day.

With email messages, I check and respond accordingly. My answerphone message suggests emailing as a support option and this is more likely to get a response after-hours because emails pipe directly through to me and they are typically quick and easy to deal with. Email support requests are also usually genuine, whereas some after-hours phone messages can be unreasonable or even abusive. Apparently, some callers expect a human being to answer at all hours!

Once the messages have been dealt with, I then go through any jobs carried over from the previous day. These jobs may be data recovery procedures that can sometimes take days as files are coaxed off dying hard drives. They can also be computers that have been



left running because their owners have complained that they either crash or show some other fault symptom but I haven't seen any evidence of this behaviour during working hours. If a machine stops overnight, I'll see the effects in the morning and that often gives me a clue as to what's wrong with it.

At this stage, I also check on what machines are due out that day and make sure the paperwork is up-to-date and that I've done everything agreed to when each machine was booked in. That done, I then remove the next machine in the queue from the incoming shelf and set it up on the workbench.

Pay up, or else!

On this particular morning, the next machine in the queue was a laptop with a scam-ware "virus" infection. People generally refer to these types of cyber-threats as "viruses", though technically they aren't because scam-ware doesn't usually attempt to replicate itself like a true virus does.

This distinction is important because almost every customer hit with hijack-ware complains their anti-virus and/or anti-malware software doesn't detect it (and thus won't remove it) and are annoyed the threat has been allowed to be installed in the first place. Unfortunately though, no matter how fancy your anti-virus or anti-spyware software is, it won't pick this stuff up as malicious.

To add insult to injury, in almost every case, the malware has been installed by the computer user. Invariably, they have been cleverly manipulated into doing so under the impression they are installing a legitimate product, codec or system utility.

In the case of the laptop, the scam-ware displayed a New Zealand Police logo at the top of a page of text, along with images that stretched to cover the desktop area completely, thus preventing users from getting past it to the rest of the computer. It essentially hijacks the computer by disabling Windows menus, shortcuts and other functions that would allow the threat to be stopped or otherwise dealt with.

The blurb on the page claims the user has been caught doing something illegal on-line. For example, if the threat came from a porn site, the text usually claims that the user was downloading child pornography and if it came from a music or file-sharing site, the "charge" is illegally downloading music or software.

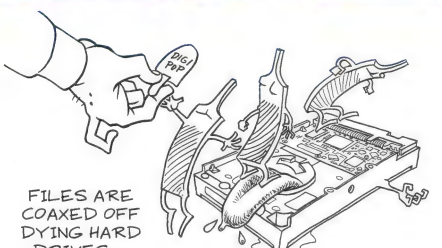
Regardless of the source, the demand is the same; payment of an instant fine or the matter would be further investigated and prosecuted. The scam is convincing; the time and date, the computer's name, the logged-on user, the IP address and, if a webcam is fitted, a snapshot of whoever was sitting at the keyboard at the time are all displayed. The scammers claim that once the fine is paid, the computer will be unlocked and nothing further said but of course this is all rubbish; the malware will keep blocking access to the computer until professionally removed.

Removing the threat

To remove this threat, I use a custom USB flash drive and boot outside the Windows environment. I can then browse the hard drive and manually remove all the files, registry entries and shortcuts created at the time of installation.

Depending on the type of threat, this usually doesn't take too long. Generally, 30 minutes is enough time to clean it all up, though this can be longer if the computer has problems booting from an external USB drive. At odd times, I boot from a CD or DVD if I can't get the USB version going.

Once I've cleaned it all out, I boot into Windows and tidy up. If the client wants a general service, I do that as well. This typically involves deleting things such as temporary files and folders, along with any other rubbish that's built up over time, and then



optimising the system to work as well as it possibly can.

Computers are a bit like cars in that they respond well to a decent service and if done once a year or every 18 months, this can keep a machine going great guns for years. We have a 50-point service plan we carry out on such machines and this ensures that everything is as up-to-date as it can be (drivers, Windows OS and other software updates, etc).

Optimising a computer for best possible performance also involves defragging the hard drive(s) and that's the last step on the list. And so, having cured this particular laptop's ransom-ware ills, I started the defragging process and left it to run while I moved onto the next job in the queue.

Forgotten password

This next machine was a PC and it had a very typical problem; someone in the household had been playing around in the users' area of the Control Panel and had set a log-on password which they had then promptly forgotten. It's mainly kids that do this sort of thing but every now and then it will be Dad who is to blame (not that he'll ever admit it).

Either way, getting into that profile without the password is a difficult-but-not-impossible task for the average computer user so it usually ends up in a serviceman's workshop. Fortunately, there are numerous utilities out there on the web for resetting Windows login passwords and they vary in price from free to expensive. The good news is you don't need to pay for such a utility; the one I use is a freeware command-line utility and works with every version of Windows since NT 4.0.

In fact, many of the shareware utilities appear to be based around the one I use except with a graphical interface tacked on. Although they undoubtedly work, I prefer to stick with my original.

The trick with these utilities is that you have to boot from either a CD or a USB drive with the software preloaded onto it. That's no big deal for most machines but some very new computers using AHCI (Advanced Host Controller Interface) technology can be problematic in that when booting to utilities like this, the software can't always load or "mount" the hard drive, making it impossible to edit the contents.

In such cases, a simple BIOS tweak will invariably allow the tool to detect and mount the hard drive but you must remember to put it back when you're done, otherwise the operating system on the hard drive will no longer boot!

Once the command-line utility I use has started, it's relatively straightforward to change or reset the user password (among other things). However, there is always the potential for catastrophe when messing about with Windows registry hives so care must be taken. Blanking the password is the recommended option and this is what I usually do.

The risk with this utility comes about when writing the altered registry hive back to the hard disk but in all my years of doing these password resets, I've never had a problem (touch wood!). That said, be warned: you use any of these utilities at your own risk. Get it wrong and you could end up with a corrupted registry and a computer that won't boot, so make sure you know what you are doing.

With the password blanked, I was now able to boot the machine and log into Windows without any problems. So that was another job done.

Damaged power button

The next machine arrived with a damaged front-panel power switch. Apparently, the pushbutton switch had failed to turn the machine on the last time it was used and in typical male fashion, its owner thought that pushing it harder would help. It didn't and when bright spark pushed even harder the whole pushbutton assembly disappeared down into the bowels of the case.

I soon had the front of the case off, so that it was now hanging by the various cables connecting the USB ports, indicator LEDs and other pushbutton switches. And the problem was obvious; two plastic clips that usually held the microswitch firmly in place had snapped off. One of the wires to the switch has also come adrift, which is probably why it had stopped working in the first place.

The only viable solution, other than replacing the entire case front, was to glue the switch back into place and so that's what I did, using 24-hour epoxy resin. The broken plastic clips were long gone so I bound the switch between what was left of the plastic mouldings using a length of thin hook-up wire. I then smothered everything with resin before covering it all with a short length of 15mm heatshrink tubing, which I then shrank into place with a hot-air gun.

I can guarantee that that particular switch isn't coming out again (although you never know with some people)!

With the switch fixed into position, I slipped some heatshrink over the loose wire and resoldered it in place. The heatshrink was then pushed over the joint and shrunk down.

A quick test proved that the machine now worked as expected, so I reassembled the case and it was "job done". This machine had been serviced not long ago so I only gave it a quick once-over to ensure everything was as it

should be before doing the paperwork, calling the client and sitting it on the outgoing shelf.

At this point, I decided to take a break from servicing and move onto a few office chores. Among other things, this involved going over yesterday's receipts with our cashbook software and making sure I hadn't made any data entry errors. This all checked out, so I backed up the cashbook files to an external drive that I take home with me.

The last waltz

My last job for the day was an aging laptop that boots but has a blank screen. However, when it's held at a certain angle, I can just faintly see the Windows desktop, a sure indication that the screen back-lighting isn't working.

There are a couple of likely scenarios here; either the back-light itself has failed or the inverter that drives the back-light system is faulty. Fortunately, both are easy enough to check once access has been gained.

The first step was to remove the screen surround. That's done by removing six tiny screws hidden beneath hard rubber bumpers and then going around the edge with a case opening tool to release the clips holding the surround in place.

Having gained access to the inverter, I unplugged the screen's backlight and plugged in a backlight tube I'd previously salvaged from a cracked screen (and which I keep just for this purpose). The tube flickered into life, proving that the inverter was OK and that it was the screen's back-light that had failed.

Unfortunately, a replacement screen is the only feasible repair option and I don't have a serviceable used one among my pile of old machines. Given the cost of a new screen, the client has a tough decision to make as to whether to go ahead with the repair or cut his losses and buy a new laptop. I'll call and leave a message with all the options and will no doubt hear from him tomorrow.

And that's another average day done. All that's left is to shut everything down and set the alarm as I leave. Tomorrow will be more of the same but then, there's always those extra special jobs that are waiting just around the corner. They're the ones that add interest and provide a real challenge, although they're not always profitable.

Solar hot-water fault

A. F. of Kingscliff, NSW recently did the "good samaritan" bit when an elderly neighbour complained about sky-high electricity bills. His investigations soon lead him to a faulty solar hot-water system. Here's what happened . . .

I find that I am sucked into repairs in all sort of innocent ways, by the "Gods of All Things Electrical". Such was the case when my neighbour recently complained to me about the high cost of her electricity bill.

Her insistence, coupled with the fact that she is a single pensioner who is doing it tough, prompted me to take a look at her electricity accounts. She could only find the last three accounts and without much detailed analysis, it seemed she had experienced a steady increase in her power consumption over the last quarter.

I didn't want to do a lot of number crunching so I phoned her power company in the hope that given their smart meters and computers, they could give me a quick answer for the sudden increase in her power consumption. Well I was wrong on that one. The "young-sounding" gentleman on the other end of the phone was as much use as a bucket of pebbles on a sandy beach, his only explanation being that "she must be using her A/C more".

My neighbour and I both knew that this wasn't the case. It was time to start looking elsewhere.

I pulled out a calculator and some paper and started to examine the usage figures. It seemed that an increase in her "peak load" was to blame for her higher costs but what had caused this? We both knew that she was very aware of the recent price rises and was careful with her appliances. What's more, she had a solar hot water system, so that ruled out any increases from that area . . . or did it?

I had run out of ideas to explain her increases, and more to stretch my legs than anything else, I asked if I could take a look at the solar hot water system. She took me to the laundry, where a cylindrical hot water stor-

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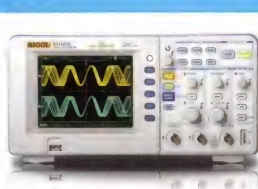

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age tank was installed in the corner. I could see the two copper pipes, which were lagged with black foam, disappear upwards through holes in the roof where they connected to the solar collector. Another single lagged pipe ran sideways and carried the hot water into the house.

I felt the pipes which ran up through the roof and was surprised to find that they were both at room temperature, especially as the sun had been shining on the roof for several hours. During this time, hot water from the solar collector panels should have been pumped down to the storage tank, making one of the roof pipes hot. So why was the hot water not being pumped down?

An ABS plastic box with electrical wires running from it was mounted on the side of the water tank. This box also carried red and black RCA sockets, with audio-type cables plugged into them. One of these cables ran up to the roof, while the other ran to a brass "plug" on the side of the tank.

A quick search on the internet soon make sense of this – there is a temperature sensor in the water tank and another immersed in the water in the solar collector on the roof. If the water on the roof is hotter than the water in the bottom of the storage tank, the roof hot water is pumped down into the storage tank until the temperatures are nearly equal.

There was a label on the outside of the ABS box, marked "No Lights On = Controller is on Standby. Green Light On = Pump is Running. Green Light Flashing = Tank Sensor Lead Fault. Red Light Flashing = Roof Sensor Lead Fault". But where were the green and red lights? I removed the cover from the ABS box and spotted a circuit board with two LEDs on it, one red and the other green. And the red LED was flashing, indicating a fault in the roof collector sensor circuit.

Next, I switched off the power to the unit, removed the RCA plugs and measured the resistance of the sensors. The one on the water tank measured 15kΩ but the one going to the roof sensor was open circuit.

This meant that either the roof sensor or the cable running to it was faulty but was that the only problem? I wanted proof that the rest of the system and the pump were still working OK, so I fished out a spare RCA audio lead from my spare parts box and soldered a 50kΩ pot to one end. I then plugged this into the roof sensor socket and wound the pot up to about its 3/4-position.

Next, I made sure that the pot was suspended in mid-air (as I was not sure what voltage was applied to it) and switched on the power at the wall socket. After about a second, I heard a click from the ABS box as the relay energised. I then waited about 20 seconds with my hands on both the lagged roof water pipes and was rewarded when one of them began to heat up. In fact, it quickly became so hot that it nearly burnt my hand.

Of course, this was due to the fact that the hot water from the roof collector was now being pumped down, indicating that the system was working correctly. I subsequently left the pump running until the pipe began to cool and then switched it off.

After that, I turned the pump on and off several times to experience the wonder of the Sun creating such hot water and it worked perfectly each time. It was now time to sort out the sensor problem.

Further checks quickly revealed that the roof sensor itself was OK (it also measured 15kΩ). Instead, the fault was due to a break in the sensor cable, somewhere between the cable going into the roof at the collector end and coming out at the laundry roof end.

At this stage, I decided to let a local plumbing company take over the job. Removing the long corrugated roofing sheets on my own, under gusting wind conditions, would be too much for me. It was a two-man job and this was proven when the workers arrived to do the repair. There were two of them, one a plumber and the other an electrician.

So why did the cable break? I didn't watch the repair but one of the servicemen later told me that there were rat droppings inside the roof and that a rat had chewed through the cable.

In the end, the repair cost my neighbour $240 but that will be recouped in the long run. It's just a pity that it took so long to find the reason for her higher charges. It makes me wonder just how many other households are obtaining their hot water from peak load electricity and paying more than they should because their solar hot water system isn't working correctly.

Samsung 740N monitor

Regular contributor B. P. of Dundathu, Qld recently tackled a faulty Samsung monitor he scrounged from a mate. Here's his story . . .

Tim Matthews (not his real name) runs an appliance repair shop and also does computer repairs. I called in to see him a few weeks ago and he handed me a Samsung SyncMaster 740N monitor. He said that a customer had brought his computer and the monitor in for repair after a car had hit a power pole outside his house, causing a blackout while he'd been using the system.

After the power had been restored, his computer and monitor both no longer worked. The computer just needed to have its power supply replaced but the monitor repair was judged to be uneconomic. As a result, the customer decided to buy a new monitor and left his old one for Tim to get rid of.

Was I interested in it? Well, yes, so I took it home and took a look at it. Unfortunately, when I tried to power it up, it was totally dead so I dismantled it and removed the power board.

I had expected to see one or more bulging electrolytic capacitors on this PCB but they all looked fine. I then checked them with my ESR meter

Servicing Stories Wanted

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and they all tested good, including the main electro after the bridge rectifier. The two fuses were also still intact and apart from a couple of suspected dry joints, I could see nothing obvious as to why the monitor was dead.

I touched up the suspect joints, reconnected the power board and powered up the monitor, not really expecting it to work. It didn't so I removed the power board again and took a close look at the layout of the power supply section. In the end, my suspicions centred on a 6-pin device designated "DM0565R". This is an integrated Pulse Width Modulator & Sense FET, specifically designed for high-performance switchmode power supplies. It was the most likely culprit but I had no way of testing it other than by substitution.

Fortunately, I had a spare 740N power board on hand that had a fault I had been unable to fix. It would power up the monitor but then the inverter section would switch off after a few seconds, so I knew that the DM0565R FET was OK. As a result, I used this to replace the suspect one, then refitted the board and powered up the monitor again.

This time, the power LED came on and flashed on and off about once a second, so I wasn't out of the woods yet. I suspected that there were further faults on the power board but the trick was knowing where to start looking. Fortunately, I also have a known good power board on hand for these Samsung monitors, so I changed it over. The power LED still flashed on and off, so the fault lay somewhere else.

The only other module that could cause this situation was the video board. Once again, my spare parts bin came to the rescue. I also just happened to have a spare video board on hand because, some time ago, I'd been given most of a 740N monitor in pieces. It was missing the screen because the person giving me the bits had swapped it into another monitor that had poor back-lighting.

Anyway, I fitted the spare video board and again powered up the monitor. And this time it worked, so I swapped over the power board to the original one and once again, the monitor worked. I then put the spare power board away and marked the original video board as faulty and placed it in my spares box. I keep dead boards because they are handy for parts when working on other equipment.

I have now repaired several of these Samsung SyncMaster 740N monitors but this is the first time I have encountered a faulty video board. I suspect the power surge had damaged the video board before taking out the DM0565R FET. In this case, it was fortunate that I had a spare video board on hand, otherwise the monitor would have been unrepairable as these boards are not available as a spare part.

Having successfully repaired that monitor, I then thought that I might as well look at another faulty 740N monitor I had in the garage. This monitor would initially light its power LED for a few seconds but then turn off completely.

I went through the usual procedure of dismantling the monitor and extracting the power board. On this occasion, I could see five dead electrolytic capacitors with obvious bulges and I also noticed that the main electrolytic capacitor following the bridge rectifier had gone very slightly convex on the top. I then checked both fuses and found that the main fuse was intact while the 3A Pico Fuse was open circuit.

The parts need to repair this board were all on the spare power board that had just donated the DM0565R FET. As a result, I swapped the capacitors and Pico Fuse over, refitted the power board to the monitor and tested it. It worked perfectly, so I now had two perfectly good Samsung 740N monitors.

The faults in the second 740N are typical of what goes wrong with these monitors. Usually, there will be three or more dead electrolytic capacitors on the power board. However, it's not so common for the main electrolytic capacitor after the bridge rectifier to be faulty and the Pico Fuse is usually OK.

Occasionally, other faults also occur that cannot be traced due to the substantial number of surface-mount components on the PCB. What's more, some of these components are virtually impossible to identify, having no part numbers or obscure part numbers that are meaningless to anyone except the manufacturer.

In cases like that, the only option is to replace the entire power board which is exactly how I happened to have the spare faulty board that I used to repair the two monitors I got going. It really pays to keep faulty boards as a source of spare parts. SC

So, what did we end up with from this salvage exercise? As you can see above, we got the following parts:

2 large transistors
1 medium transistor
6 small transistors
2 large dual switching diodes
2 small dual switching diodes
1 600V 6A bridge rectifier
1 3A diode
1 fuse and clips
1 thermistor
2 250V electrolytic capacitors
1 X2 rated mains capacitor
3 medium sized electrolytic capacitors
12 smaller electrolytic capacitors
3 greencaps
8 ceramic capacitors
2 heatsinks
1 120mm 12V fan and grille
(Most power supplies are fitted with an 80mm fan)
4 cable ties
Several screws of different types
Transistor insulators
Several chokes & transformers (limited use?)
Several lengths of light and medium hookup wire
A 230V switch
A 230V IEC socket with X2 filter capacitor and choke
A couple of computer connectors which we kept with wire
1 sheet of insulating plastic from under the circuit board

Overall, a worthwhile exercise that yielded a variety of useful parts for the junk box.

Amongst the parts was a splitter cable consisting of a Molex connector to two SATA connectors. This was kept intact as a spare part for possible use in upgrading a computer from an IDE drive to a SATA drive, or adding extra SATA drives where there weren't enough SATA connectors on the existing power supply.

There was also a P4 connector, which the wire was left on. If needed it can be spliced into an older power supply that is lacking a P4 connector.

As well, there were two standard computer cables consisting of two molex connectors and one floppy connector. These were retained as spares, but probably won't be needed, as floppy drives are rare these days and most drives are now SATA. It could be handy for an antique computer though! The rest of the hookup wire had the connectors cut off and the hookup wire was sorted into colours and sizes for storing for later use as needed.

There is a wide variety of computer power supply manufacturers and you may not find all the mentioned components in all power supplies. In fact, some power supplies will have additional components in them, such as voltage regulators and more transistors and different types of heatsinks. Modular types of power supply will also have a variety of different plugs and sockets that may be of use.

There will almost always be one or more integrated circuits in every different type of computer power supply, however, there is a fairly high chance of these ICs being faulty if the power supply no longer works and it's unlikely that a suitable method of testing them will be available.

Therefore, I never bother salvaging them, unless I need a particular type and I can remove it from a known working power supply that isn't worth keeping, for reasons such as the case being very rusty or the power supply being so old that its rating is too low to be of any use for a reasonably modern computer.

I usually don't bother with salvaging small signal diodes, 1A rectifier diodes, small resistors and small capacitors, as these are harder to remove and of limited use with their short leads. However, these components can be salvaged if they are of any use, as otherwise they will be binned with the circuit board.

In some cases, it may be worthwhile saving the case, if there is a need for it for a project, as it has an inbuilt fan and vents. However, I don't usually bother saving the case in most cases, because it is often rusty anyway. I usually just flatten it and toss it in the recycle bin, along with the circuit board.

The last point to be considered when salvaging parts, is that it is very important to **test all salvaged parts** before they are used in a repair or a project. Remember, they might have caused the fault in the first place!

If you can't test a component (because of a lack of test gear suitable for testing that component), **then don't use it!**

It's no use putting a potentially faulty component into a piece of equipment or a project, because you could be just introducing a fault.

(Ed note:) As far as semiconductors are concerned, an analyser such as the Peak Atlas DCA is definitely worthwhile (available from Altronics – cat Q2100). It will not only tell you what the device is – ie, transistor, SCR, etc, (including its parameters) it will also identify leads – very handy when you don't know what you've pulled out. SC

NEXT MONTH: OK, so you've got all the bits from the power supply. But what goodies are worth saving on the motherboard?

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In-store only. Limited stock. Not available online.

4 Port USB 2.0 Networking Server

Share USB powered devices across a network. Ideal for printers, scanners or for access to your external hard drives.

- Supports up to 4 devices at the same time

YN-8406 **WAS ORRP $69.95**

In-store only. Limited stock. Not available online.

$44.95

SAVE $25

ExpressCard Gigabit Ethernet

Slot this ExpressCard into the 34mm socket on your laptop for gigabit network capabilities. The device will auto-negotiate to 10/100/1000Mbps networks.

- Compatible with Win2000/XP
- Fully plug and play and hot plug compatible
- Size: 34(W) x 15(H) x 117(D)mm

XC-4146 **WAS ORRP $69.95**

$24.95

SAVE $45

SAVINGS on Outdoor Products!

12V 10W Amorphous Solar Panel

Features an aluminium picture type frame and clear glass window to ensure long life, reliability and protection from the elements. Supplied with 1.5m interconnecting lead with 3" alligator clips.

- Temp Range -50˚C to 70˚C
- Size: 930(H) x 320(W)mm

ZM-9030

WAS ORRP $89.95

In-store only. Limited stock. Not available online.

$59.95

SAVE $30

Outdoor USB Solar Charger

Provides a 5V USB port suitable for charging devices such as media players and Smartphones. Attach it to a backpack, tent, or bike using the elastic strap and clips to charge on the go.

- Peak Current: 500mA
- Size: 250(H) x 170(W) 15(D)mm

MB-3593

WAS ORRP $44.95

$34.95

SAVE $10

iPhone® not included

CLEARANCE SALE

Jaycar Electronics — Better, More Technical

Savings

Biometric Fingerprint ID Access Control

Control a single door or use multiple units on a site connected to a PC via an RS232, RS485 or Ethernet connection. Software included.

- 12VDC 3A relay output
- Requires 9VDC @ 500mA
- Size: 180(L) x 82(W) x 55(H)mm

LA-5121 **WAS ORRP $499.00**

$199.00

SAVE $300

In-store only. Limited stock. Not available online.

8 Zone Wireless Alarm Kit

The system "learns" what sensors are connected and the part arm function allows you to protect certain zones while others are disarmed. Easy to install, ideal for rented or temporary premises.

- Kit includes siren, keypad, PIR sensor, reed switch and power supply

LA-5150 **WAS ORRP $169.00**

$149.00

SAVE $20

Rechargeable Emergency Sensor Spotlight

An emergency lighting solution suitable for hallways, entry and exit points. The mains power supply charges the internal battery to ensure illumination is available during power outages. Also acts as a standard PIR spotlight to illuminate paths when motion is detected.

SL-3232 **WAS ORRP $69.95**

$64.95

SAVE $5

Home Theatre Powerboards

Keep your home theatre equipment safe.

- Data via a network connection
- Satellite/cable TV and TV aerials
- 8 surge and spike protected outputs

Home Theatre Powerboard

- USB outlets
- 52kA max surge current
- 1550J Energy absorption

MS-4024 **WAS ORRP $49.95 NOW $39.95 SAVE $10**

High End Home Theatre Powerboard

- Telephone protection
- 144kA max surge current
- 4300J energy absorption

MS-4029 **WAS ORRP $79.95 NOW $59.95 SAVE $20**

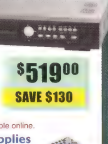
MS-4024

FROM $39.95

SAVE $10

Network 4Ch DVR with 4 x 520TVL CCD Cameras

View live and/or recorded footage anytime, anywhere! Contains multiplexing DVR with Ethernet access, four weatherproof CCD cameras with IR illumination, and four 20m cables.



- 704 x 576 D1 resolution @ 100IPS
- 500GB SATA Hard disk
- 520TV line cameras
- DVR size: 343(W) x 240(D) x 68(H)mm

QV-8108 **WAS ORRP $649.00**

$519.00

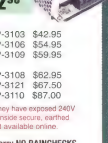
SAVE $130

In-store only. Limited stock. Not available online.

Switchmode Power Supplies

High efficiency and reliability. Features overload protection, current limitation, screw down terminals and strong metal cage.

- Built-in EMI filter



FROM $42.95

24V		
25W	MP-3103	$42.95
40W	MP-3106	$54.95
60W	MP-3109	$59.95
12V		
60W Dual Output (5/12V)	MP-3108	$62.95
120W	MP-3121	$67.50
150W	MP-3110	$87.00

NOTE: These are not stand alone units. They have exposed 240V terminals. They are meant to be mounted inside secure, earthed cabinets. In-store only. Limited stock. Not available online.

Listed below are a number of discontinued (but still good) items that we can no longer afford to hold stock.
Please ring your local store to check stock. At these prices we won't be able to transfer from store to store. **STOCK IS LIMITED. ACT NOW TO AVOID DISSAPOINTMENT. Sorry NO RAINCHECKS.**

Test & Tools

Cat No.	Product Description	Original RRP	Special Price	SAVE
TH-1930	Assembly Tool for Solar Power Connectors	$9.95	$4.95	$5.00
TD-2176	Bicycle Toolset 6-pce Stainless Steel Foldout	$19.95	$11.95	$8.00
TD-2111	Bit Set Mixed 18-pce Stainless Steel	$29.95	$19.95	$10.00
QM-1496	DMM Autoranging SMT	$69.95	$39.95	$30.00
WT-5342	DMM Leads with Mini Blade Fuse Fitting	$11.95	$6.95	$5.00
QM-1546	DMM Solar Rechargeable	$119	$59.00	$60.00
TH-1992	Glue Gun Large 240V	$22.95	$10.95	$12.00
TD-2522	Hole Saw Adjustable	$79.95	$39.95	$40.00
QM-1515	Magnetic DMM Strap	$5.95	$3.95	$2.00
TH-1877	Pickup Tool Magnetic with LED	$9.95	$7.95	$2.00
TD-2130	Tapered Reamer 3 - 12mm	$9.95	$7.95	$2.00
TH-1806	Tool Set 10-pce Alignment	$6.95	$4.95	$2.00

IT

Cat No.	Product Description	Original RRP	Special Price	SAVE
XC-4876	12 Volt ATX Computer Power Supply for Cars	$99	$69.00	$30.00
XC-4899	2 x e-Sata + 2 x Main Molex Front Panel	$19.95	$12.95	$7.00
XC-4147	2 x USB 3.0 Port Upgrade Kit	$39.95	$34.95	$5.00
AR-3280	Antenna 2.4GHz Dipole MIMO 7dBi	$49.95	$14.95	$35.00
AR-3282	Antenna 2.4GHz Yagi Wi-Fi	$29.95	$19.95	$10.00
AR-3313	Antenna 3G/4G Cellular Omni-directional	$89	$79.00	$10.00
XC-4695	Dual HDD 2.5"/3.5" SATA Dock	$79.95	$49.95	$30.00
PL-0754	HDD Adaptor 2.5" - 3.5" with Bracket	$14.95	$10.95	$4.00
GH-1898	Hub USB 4 Port with Rhinestone	$29.95	$13.95	$16.00
XC-4861	IPTV Internet Digital TV Tuner	$169	$99.00	$70.00
WC-7570	Lead - Computer Keyboard/Mouse to suit PS2® Switchbox	$19.95	$7.95	$12.00
WC-7640	Lead - FIREWIRE IEEE1394 4PM-M 2m	$12.95	$6.95	$6.00
WC-7645	Lead - FIREWIRE IEEE1394 6PM-M 5m	$19.95	$12.95	$7.00
WV-7436	Lead - Nintendo Wii® S-Video Upgrade Cable	$29.95	$9.95	$20.00
WV-7430	Lead - Playstation® AV 1.8m	$29.95	$9.95	$20.00
YN-8209	Lead - Retractable Cat 5 1.5m	$7.95	$3.95	$4.00
WV-7434	Lead - Playstation® S-Video Upgrade 1.8m PS3®	$35.95	$7.95	$28.00
WC-7730	Lead - Retractable iPhone®/iPad®/iPod® to USB A Socket White 1m	$14.95	$11.95	$3.00
WC-7782	Lead - USB 3.0 A Male to B Male - 2m	$19.95	$14.95	$5.00
XC-4843	PCMCIA Fingerprint ID for Laptops	$129	$59.00	$70.00
XC-4252	Power-over-Ethernet Regulator 802.3af Compliant for Arduino	$29.95	$24.95	$5.00
XC-5188	Speaker Active Desktop with MP3	$59.95	$34.95	$25.00
XC-5189	Speaker with Aux-In - Suits iPod	$19.95	$5.95	$14.00
XM-5040	USB 5-Button Laser Mouse	$17.95	$14.95	$3.00
XC-4908	USB Business Card Scanner	$79.95	$39.95	$40.00
XC-4910	USB Photo Scanner	$129	$69.00	$60.00
ZZ-8820	Wafer Card - Emerald	$14.95	$7.95	$7.00
ZZ-8810	Wafer Card - Silver	$19.95	$7.95	$12.00

Security

Cat No.	Product Description	Original RRP	Special Price	SAVE
QC-3599	2.4GHz Wireless AV Modules - Receiver	$29.95	$16.95	$13.00
QC-3264	Dome Kit with 2-Wire Camera	$129	$49.00	$80.00
QC-3293	Armour Dome Sensor CCD Camera	$149	$79.00	$70.00
QC-3467	Bullet B&W CCD Camera	$99	$45.00	$54.00
QC-3301	Day/Night Colour Hi-Res CCD Camera	$299	$119.00	$180.00
QC-3299	ExView HAD Colour High Res Pro Style	$349	$139.00	$210.00
QC-3298	ExView HAD Colour Pro Style CCD Camera	$249	$109.00	$140.00
QC-3289	Wide Dynamic Pro Style CCD Camera	$449	$349.00	$100.00
QC-3341	Camera Lens CS Mount 4mm for Professional Surveillance Cameras	$24.95	$19.95	$5.00
QC-3317	Camera Lens Standard C-Mount F2 8MM	$24.95	$16.95	$8.00
QC-3283	CCTV Video/Power Processor 2-Wire	$89.95	$74.95	$15.00
QC-3265	CCTV Video/Power Processor 4-Channel	$299	$169.00	$130.00
ZZ-8954	Clear 21mm Diameter RFID Tag	$5.95	$3.95	$2.00
QC-3186	Diving Mask with Digital Camera 2GB	$129	$89.00	$40.00
LA-5022	Doorbell - Wireless	$34.95	$24.95	$10.00
QV-3028	DVR Kit 4Ch with 4 Colour Cameras	$379	$349.00	$30.00
LA-5300	Light Strobe 12V Blue	$29.95	$24.95	$5.00
LA-5049	PIR Presence Detector Recessed 360 degree	$29.95	$24.95	$5.00
LA-5041	PIR Pulse Count 360 degree	$169	$89.00	$80.00
LA-5122	RFID & Fingerprint Access Controller	$299	$99.00	$200.00
LA-5123	RFID Keypad Access Controller	$169	$75.00	$94.00
QC-8005	Video Camera Mini 3MP HD	$119	$69.00	$50.00
QC-3608	Video Door Phone Slimline 7" LCD Colour	$199	$129.00	$70.00
QC-3604	Video Door Phone Slimline LCD Colour	$149	$129.00	$20.00
QC-3628	Video Door Phone with 4-Ch Recording 8" LCD	$549	$479.00	$70.00

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DIY PACKAGES

10 Zone Alarm Kits

Fully configurable and programmable. Includes a central controller and the sensors you need to get a basic system up and running. Up to four remote keypads can be installed at up to 100m range and each can be named for easy identification.

- Programmable timers for entry, exit and alarm duration
- Kit includes: control panel, infrared LED controller, PIR sensors, reed switch, bellbox, 50m 6 core cable and 12V 1.2Ah backup battery

LA-5560 **WAS $199.00**

$149.00
SAVE $50

In-store only. Limited stock. Not available online.

8 Zone Wireless Alarm Kit with GSM Dialler

Package deal with 8 Zone Wireless Alarm Kit (LA-5145) and GSM Dialler (LA-5164) so you can be notified with a phone call when the alarm has been tripped.

Includes:
- LCD control panel
- Key fob remote
- PIR sensor
- 2 x reed switch sensors for doors or windows
- Key fob remote with panic button
- Telephone Dialler (LA-5133)

LA-5169 Note: LA-5164 requires a SIM card.

NEW

$299.00

D1 Resolution DVR Kit with 4 IR Cameras

Package includes full function DVR, four weatherproof CCD cameras, and 500GB of storage for over 300 hours continuous video recording. With the help of a free app for Smartphone/iPhone® or the internet, you can log into a system from anywhere to view live and/or recorded footage. See website for full specifications.

- H.264 video compression
- 704 x 576 pixel (D1) resolution
- 420TV line CCD cameras
- Power supply and 4x 20m cables included
- DVR size: 343(W) x 240(D) x 68(H)mm

QV-8106 **WAS $549.00**

Extra cameras available: High Resolution CMOS Cameras with IR Illumination QC-8632 $99.00

$449.00
SAVE $100

In-store only. Limited stock. Not available online.

Pro Soldering Gas Kit

Excellent value and ideal starter kit.

- Kit contains pro gas soldering iron with tips, cutters, desolder braid, electrical shears, wire stripper/cutter crimpers solder splice heatshrinks and heat shrink pack

TS-1114

$99.00

25W Soldering Iron Starter Kit

This kit contains everything needed for working on basic electronics projects or automotive circuits. Includes a digital multimeter, soldering iron, de-soldering tool, screwdrivers, pliers and side cutters.

TS-1652

$34.95

QC Crimp Connector Pack

This pack contains 300pcs of only the most commonly-used quick connectors from our range of separately sold QC connectors. Insulation is injection-moulded Nylon rated to 105˚C, with a moulded funnel taper in the insulation for easy cable entry. See website for full specification.

PT-4536

$34.95

PCB Etching Kit

An ideal kit for anyone needing to etch a circuit board - complete with an assortment of double-sided copper boards, etchant, working bath and tweezers. See website for full list of inclusions.

HG-9990 **WAS $27.95**

$17.95
SAVE $10

AUDIO SPOT SPECIALS

Turntable

Listen to vinyl collections directly from the unit. Features a 3.5mm headphone jack for personal listening with adjustable bass control and a line level output for connection to an external amplifier.

- 33/45/78 RPM
- Stereo amplifier
- Automatic stop
- Size: 350(L) x 310(D) x 130(H)mm

GE-4136 **WAS $49.00**

$39.00
SAVE $10

Wireless Stereo Headphones

Enjoy high-quality stereo sound from the built-in FM radio or from audio devices such as a TV, PC or Hi-Fi. Transmitter charging cradle runs on the included mains AC adaptor or requires 3 x AAA batteries.

- Frequency response: 22 - 20kHz
- Transmission range: 15m
- Cradle size: 215(W) x 68(H) x 135(D)mm
- Headphone size: 205(W) x 200(H) x 85(D)mm

AA-2071 **WAS $79.95**
In-store only. Limited stock. Not available online.

$59.95
SAVE $20

Steelmate Car Alarm - Basic

An affordable car alarm that features voice feedback on alarm status and operational parameters such as open doors etc. Comes with code hopping remotes.

- Boot release button
- Valet mode
- Anti-hijacking, emergency call & locating
- Emergency override

LA-9003
WAS $99.00

$89.00
SAVE $10

Front and Rear Parking Assist Kit

While most reversing systems cover the rear of a vehicle they do nothing for the blind spot on the nose. This system covers both areas with 8 sensors and the LCD display clearly indicates the distance to objects in both directions with an audible alarm sounds if you get too close.

- Input voltage: 9-16VDC
- Display size: 104(W) x 75(D) x 41(H)mm

LR-8872 **WAS $179.00**

In-store only. Limited stock. Not available online.

$169.00
SAVE $10

Reversing Camera with Sensors & 3" LCD Monitor

Scans the rear of the vehicle for any object within the detection range appearing on the monitor with changing tones. System includes four sensors, a camera, and a 3" TFT LCD monitor.

- PAL or NTSC mode available
- Power: 12V DC
- Anti-false alert technology

LR-8870 **WAS $199**

Also available: 2.4GHz DIGITAL Wireless Reversing Camera Kit QM-3802 WAS $249 NOW $229 SAVE $20

$179.00
SAVE $20

To order call 1800 022 888

www.jaycar.com.au

Savings off original RRP. Limited stock on sale items

KITS - BUILD THEM

Jaycar electronics
Better. More Technical.

Pre-Amplifier Kits

"Pre-Champ" Versatile Pre-amplifier

This tiny pre-amp was specifically designed to be used with the 'Champ' amplifier (KC-5152). Unless you have a signal of sufficient amplitude the 'Champ' will not produce its maximum power output. The 'Pre-Champ' is the answer with a gain in excess of 40dB, which is more than enough for most applications.

- Power requirement 6-12VDC.
- Kit includes PCB and electronic components
- PCB: 46 x 36mm

KC-5166

$8.95

Universal Stereo Pre-amplifier

Designed for use with a magnetic cartridge, cassette deck or dynamic microphone. The performance of this design makes it a worthy replacement if your current pre-amp falls short of expectation. It features RIAA/IEC equalisation, and is supplied with all components to build either the phono, tape or microphone version.

- +/- 15VDC required.
- PCB: 80 x 78 mm

KC-5159

$16.95

Digital Audio Delay Kit

Corrects sound and picture synchronisation ("lip sync") between your modern TV and home theatre system. Features an adjustable delay from 20 to 1500ms in 10ms steps, and handles Dolby Digital AC3, DTS and linear PCM audio with sampling rate of up to 48kHz. Connections include digital S/PDIF and optical Toslink connections, and digital processing means there is no audio degradation. Kit includes PCB with overlay a pre-soldered SMD IC, enclosure with machined panels, and electronic components.

- 9-12VDC power supply required
- Universal IR remote required
- PCB: 103 x 118mm

KC-5506 Limited stock

$99.95

Automotive

10A Motor Speed Controller

Ideal for controlling 12VDC motors in cars such as fuel injection pumps, water/air intercoolers and water injection systems. The circuit incorporates a soft start feature to reduce inrush currents, especially on 12V incandescent lamps.

- Kit includes PCB plus all electronic components to build the 10A version.
- PCB: 69 x 51mm

KC-5225

$24.95

Headlight Reminder Kit

Features include a modulated alarm, ignition and lights monitoring, optional door switch detection, time-out alarm and a short delay before the alarm sounds. Kit includes quality solder masked PCB with overlay, case with screen printed lid and all electronic components.

- 12VDC
- PCB: 78 x 49 mm

KC-5317

$27.95

High Energy Ignition Kit for Cars

Use this kit to replace a failed ignition module. Use with any ignition system that uses a single coil with points, hall effect/lumenition, reluctor or optical sensors (Crane and Piranha) and ECU.

- Kit supplied with silk-screened PCB, diecast enclosure (111 x 60 x 30mm), pre-programmed PIC and PCB mount components for four trigger/pickup options

KC-5513

$49.95

Multi-Channel Remote Control Relay Boards

Add remote control functions to a new project or existing installation with these handy remote control relay boards. Each channel can be set to momentary or latching mode allowing you to customise the setup to suit your application.

- 40m max transmission range
- 12VDC

2 Channel
- Size: 85(L) x 61(W) x 20(H)mm
- Spare 2 channel key fob controller also available (LR-8856)

LR-8855 $34.95

4 Channel
- Size: 90(L) x 73(W) x 20(H)mm
- Spare 4 channel key fob controller also available (LR-8858)

LR-8857 $49.95

LR-8855

LR-8857

NEW FROM $34.95

Soft Start Kit for Power Tools

Stops that dangerous kick-back when you first power up an electric saw or other mains-powered hand tool to prevent damage to the job or yourself. Kit supplied with PCB, silk screened case, 2m power cord and specified electronic components.

- 240VAC
- 10A
- PCB: 81 x 59mm

KC-5511

$49.95

Digital Multimeter Kit

Learn everything there is to know about component recognition and basic electronics with this comprehensive kit. From test leads to solder, everything you need for the construction of this meter is included.

- Meter size: 67(W) x 123(H) x 25(D)mm

KG-9250

$24.95

Transistor Tester

Have you ever unsoldered a suspect transistor only to find that it checks OK? Troubleshooting exercises are often hindered by this type of false alarm. You can avoid these hassles with the In-Circuit Transistor, SCR and Diode Tester. The kit does just that, test drives WITHOUT the need to unsolder them from the circuit!

KA-1119

$27.95

Power Regulators

Voltage Regulator Kit

This handy voltage regulator can provide up to 1,000mA at any voltage from 1.3 to 22VDC. Ideal for experimental projects or as a mini bench power supply etc. Kit supplied with PCB and electronic components.

- PCB: 38 x 35mm

KC-5446

$16.95

Universal Power Supply Regulator Kit

One small board and a handful of parts will allow you to create either a regulated ± 15V rail or +15VDC single voltage from a single winding or centre tap transformer (not included).

- Includes all PCB and components for board, transformer not included
- PCB: 72 x 30mm

KC-5501

$14.95

Simple 1.5A Switching Regulator Kit

Outputs 1.2 to 20V from a higher voltage DC supply at currents up to 1.5A. It is small, efficient and with many features including a very low drop-out voltage, little heat generation, electronic shutdown, soft start, thermal, overload and short circuit protection. Kit supplied with PCB, pre-soldered surface mounted components.

- PCB: 49.5 x 34mm

KC-5508

In-store only. Limited stock. Not available online.

$39.95

Jaycar Electronics — NEW for the new year

Better, More Technical

Network 16 Channel DVR Kit with 4 High Grade CCD Cameras

High performance surveillance kit includes DVR, 4 x 960H (976 x 582) high resolution colour CCD cameras with rating IP66, 18m camera cables, and 12VDC 5A power supply.

Features:
- Full WD1 (960 x 576) resolution
- Multiple video output formats
- Ethernet connection
- Capable of accepting alarm trigger signals from separate sensors
- View remotely via a web browser or iPhone®/Smartphone application*
- 1TB SATA included (accepts up to 2 x 2TB HDD)
- USB & network remote back-up
- Size: 380(W) x 340(D) x 50(H)mm

QV-3038

NEW

$1149.00

* Free app available for viewing live video. Application based searching and backup requires advanced version at an additional cost.

Wireless Presenter with Trackball Mouse and Laser

Functions include page up/down, laser pointer, trackball, mouse right/mouse left. A small USB receiver is located inside for plug-and-play.

XC-5413

NEW

$59.95

900MHz Digital Wireless Headphones with TOSLINK

Has a built-in rechargeable battery to allow you freedom to move around. The headphone docks to the transmitter and charges when not in use. Supplied with a mains power adaptor, 3.5mm stereo audio and RCA leads.

- Built-in FM radio
- Transmission range: up to 15m under optimal conditions
- Transmitter requires 5VDC or 3 x 1.5V AAA batteries

AA-2083

NEW

$79.95

Flexible 10 LED USB Light

A handy reading assistant for laptops, Tablets, PCs or books. On/off touch lamp.

- 10,000 hour led life
- Flexible gooseneck (315mm long)

ST-2807

NEW

$14.95

Note: Laptop not included

Dual Fan Notebook Cooler

Keep your notebook cool on your lap or desk. Simply plug into your USB port.

- Size: 365(L) x 295(W) x 40(H)mm

XC-5211

NEW

$14.95

Note: Laptop not included

Dimmable Rechargeable 10W LED Work Light

Features a dimmable LED for more lighting flexibility, a high-strength tempered glass cover and a high-pressure die cast aluminium shell.

- IP65 rating
- 240VAC power input

SL-2809

NEW

$89.95

Due Mid January

Solar Rechargeable Motion Sensing LED Flood Light

The 3W solar panel comes with a bracket allowing you to bolt it onto a surface to catch as much sun as possible. It's connected to a very bright 10W LED light with a 3m cable. The light also features a mounting bracket. The light is entirely controlled by the PIR sensor.

SL-2808

NEW

$159.00

Due Mid January

12VDC Mounting LED Headlamp Modules

Extremely bright drop-in replacement LED headlights for your car. Each kit contains 2 x 25W per LED bulbs, 2 x controller assemblies, and all the wiring is pre-terminated to appropriate connectors to make installation as quick and easy as possible.

SL-3499

- CREE® XLamp CXA1512 LED
- Ballast size:65(L) x 50(W) x 16(H) mm

H4 (High / Low Beam) CREE® LED Powered Headlamp Kit
- 1600/1800 Lumens per LED bulb

SL-3498 $169.00

H7 CREE® LED Powered Headlamp Kit
- 1800 Lumens per LED bulb

SL-3499 $169.00

NEW

$169.00 ea

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Prices valid from 27th December 2013 to 23rd January 2014.

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Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Stockist. These stores may not have stock of these items and can not order or transfer stock.

Jaycar Electronics — Better, More Technical

PRODUCT SHOWCASE

Saleae Logic16 Analyser

Logic16 is a logic analyser used to record, view, and measure digital signals. Logic16 also currently has 17 different protocol analysers including serial, I²C, SPI, CAN and many more. Logic16 can sample two channels at 100MHz, four channels at 50MHz, eight channels at 25MHz or all 16 channels at 12.5MHz and can record up to 10 billion samples.

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Contact:
Core Electronics Pty Ltd
35 Tipperary Dve, Ashtonfield NSW 2323
Tel: (02) 8007 4447
Website: www.core-electronics.com.au

Surround Master from Involve Audio

Involve Audio, an Australian technology development company, has released the "Surround Master" surround sound decoding system.

The SM 465 is a dual DSP based stereo to either 4 channel or 5.1 channel decoder that features a central QS based core, tri band dual slope processing and the patented Involve acoustic processing technique. The manufacturers claim greatly improved stereo decoding relative to other stereo formats such as Dolby PL2, Circle Surround, Q sound, dummy head recordings, QS RM, etc.

"Involve" is also a recording format fully compatible with stereo and achieves up to 40dB of separation using the company's encoder. It is further claimed the system is free of sonic artefacts such as pumping or surging etc.

The base model SM465 is priced at $395.00

Contact:
Involve Audio
33 Malcolm Rd, Braeside, Vic 3195
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Verbatim's LED Candle looks just like . . . a candle!

Verbatim's new "True Candlelight" LED lamps allow users to experience the warmth and ambience of candlelight. Delivering 1900K colour temperature, the white light spectrum and intensity of the LED closely matches a real candle flame – a feature not possible with traditional LED or incandescent lamps. Ideal for use in decorative lighting fixtures such as chandeliers, wall sconces and table settings, the 2.5W VxRGB candle LED has an E14 base fitting and optics that feature a flame tip design.

Contact:
Verbatim Australia
6/450 Princes Hwy, Noble Park, Vic 3174
Tel: (03) 9790 8999
Website: www.verbatimlighting.com.au

Tektronix PA1000 Single-Phase Power Analyser

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Contact:
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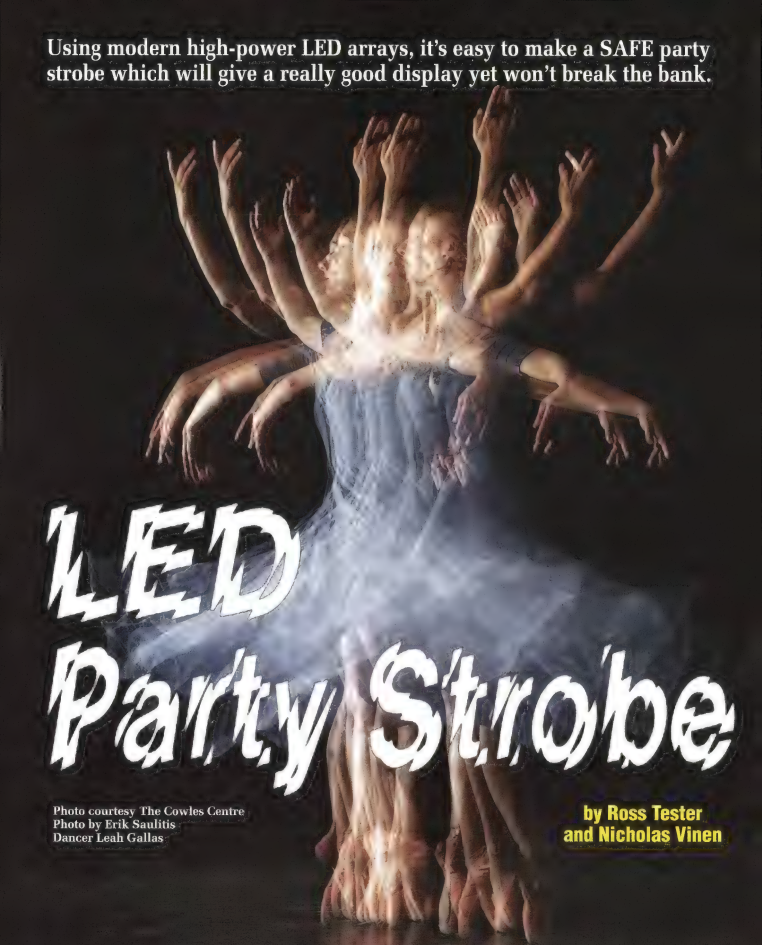
Website: www.tekmark.net.au

Correction:
QualiEco Circuits Pty Ltd
In the December Product Showcase, the phone number for the Auckland office of QualiEco Circuits was wrong. Correct contact details are: PO Box 75474, Manurewa, Auckland
Tel: (649) 269 6916 **Fax:** (649) 269 6926 **www.qualiecocircuits.co.nz**

Using modern high-power LED arrays, it's easy to make a SAFE party strobe which will give a really good display yet won't break the bank.



LED Party Strobe

Photo courtesy The Cowles Centre
Photo by Erik Saulitis
Dancer Leah Gallas

by Ross Tester
and Nicholas Vinen

The LED Party Strobe is in two parts: on the left is the power supply box which contains only the transformer and associated parts while on the right is what could be called the "head unit" with the driver electronics and the all-important 100W ultra-bright white LED array. This is housed in a LED floodlight fitting from Oatley Electronics, the same source for the LED arrays.

Many years ago, several party strobes, along with "industrial" types (we'll explain the difference shortly) were described in the magazines of the day – Electronics Australia and Electronics Today. They were very popular as kits, with Dick Smith Electronics, for example, selling thousands of the things.

But they were nasty beasts! (I was going to use another "b" word but the Editor wouldn't let me!).

The Xenon flashtubes they used required dangerously high DC voltages and invariably this was supplied straight from a rectifier on the mains, feeding a high voltage capacitor via a 10W resistor. That means there was about 350V DC or so on the (usually exposed) wires of the flashtube, ready to bite unsuspecting users. Talk about an accident waiting to happen; and they did!

Sure, the magazines described perspex covers to try to keep them a bit safer but the vast majority were built with that part conveniently left off. So after some time, the kits became unavailable – mainly on safety grounds but also, to some degree, because the psychedelic age had passed and strobes were a little passé.

Which was probably just as well, as another generation might have discovered them and discovered (the hard way) just how lethal they could be.

In recent years, though, party lighting has had something of a resurgence, if for no other reason than it is now significantly cheaper than it used to be (did someone mention China?).

By and large, though, party strobes still used those high-voltage xenon tubes. For a short, bright flash, there's nothing better. And yes, you can still buy Xenon flashtubes, although the really high power types seem to have all but disappeared.

Something safer?

But we wondered whether we could come up with a much safer and possibly cheaper alternative. You'd have noticed the proliferation of very bright LED arrays recently. Could they, would they be suitable?

But what is a strobe?

OK, we've got a bit ahead of ourselves here because many readers might not even know what a strobe is!

Originally developed for serious industrial and educational use, stroboscopes (to give them their proper name) are devices which use a very short but accurately repeated flash of light to "stop action" on (mainly) rotating objects.

They do this by synchronising the timing of the pulses so that the rotating object, eg, a fan blade, is always at the same point in its rotation as the flash occurs. With subdued lighting around the object, that flash simply highlights the object so that it appears to be stationary.

Human "persistence of vision" takes care of the rest – the eyes and brain "fill in the gaps" between each flash so that it appears you are seeing a continuous image.

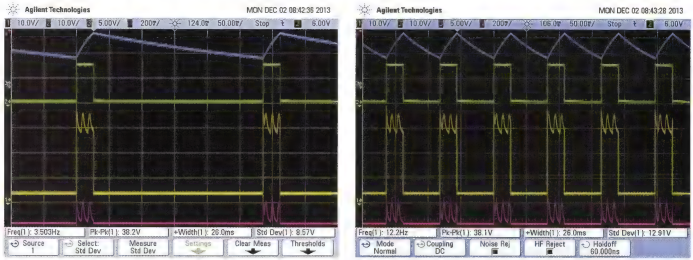
That in itself can be dangerous: many a finger has been sliced when someone who didn't understand what was happening has poked said digit into a rotating fan!

By and large, these "strobes" were relatively low power affairs; after all, you didn't want a blinding flash, you just needed enough to illuminate the subject. The frequency of operation ranged from quite slow to very fast – if the subject was spinning very fast, you needed to be able to match its speed to "stop" it.

If you varied the speed of the strobe a little away from synchronisation, you could make the object appear to be rotating forward, or backward. At half or double the speed, the object appeared to stop rotating again.

It's a similar effect to the backward-rotating wagon wheels in wild west movies, except that here the strobing occurs due to the "stop action" of the movie camera.

As mentioned above, for many years, strobes were made using small, U-shaped Xenon flash tubes, typically rated at 0.5 Joules. These have an operating voltage of 200-400V



These two scope graps show various waveforms at minimum (left – about 3.5Hz) and maximum (right – about 12Hz) flash rates. The pulse width itself remains constant at about 25ms. The top (blue) trace shows the 7555 timing capacitor charging and discharging (pin 2/6), while the green trace is the corresponding Mosfet gate voltage. The yellow trace is the voltage across the LED array itself (the sawtooth waveform on top is 100Hz ripple from the power supply). Finally, the pink trace shows the actual light output of the LED array, as seen by a phototransistor. Note that the light output exactly follows the 100Hz modulation of the power supply.

DC but require a "striking voltage" many times higher – perhaps 3-4kV and often more.

Simply connecting one of these tubes across a voltage source did nothing, that is, until the high voltage trigger pulse was applied. Then they would instantly discharge the voltage source (usually a capacitor) resulting in a bright flash of light as the Xenon in the tube ionised.

The trigger voltage was provided by a special high voltage transformer which in turn received its pulses from some form of oscillator. It was possible (indeed quite usual in party strobes) that this was very simple indeed, with as few as half a dozen parts. It was only when high precision was needed (eg, in an industrial situation where the strobe was also used to measure RPM) that a more accurate oscillator was employed.

The advantage of Xenon tubes was that the flash of light they gave, while intense, was very brief – somewhere between a few nanoseconds and a few milliseconds – dependent on how long it took for the storage capacitor to discharge through the tube.

Once discharged, the current stopped, the gas de-ionised and the tube instantly stopped glowing. The capacitor recharged, the transformer triggered the tube and this repeated while ever power was applied.

Strobes were also used in photography. Again, first of all for industrial applications but also to capture action, for example in nature, that would otherwise be impossible to see. Strobes became more powerful and more portable. The brighter the strobe flash, the better the photographic image.

Somewhere along the line, someone (probably a university student!) realised that in a darkened room, a slow-running strobe also "froze action" of a moving person. And this was never more evidenced than when that person happened to be wildly gyrating – some call it dancing.

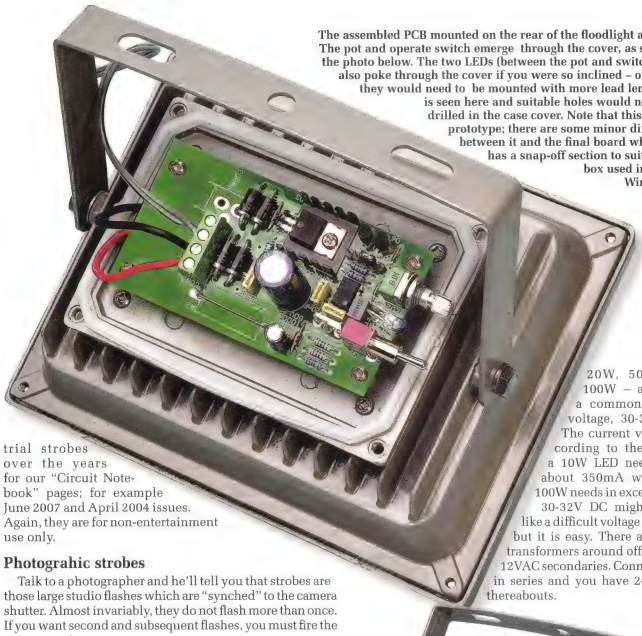
So the industrial strobe was beefed up in power and slowed right down – experimentation showed that flash rates between about five and ten flashes per second were ideal. Any slower and the images were too unrealistic and grotesque; too fast, and the action became almost like it had a continuous light shone on it.

There was a downside, however – at certain flash rates, strobes were found to induce epileptic fits in those predisposed to them (see warning panel).

With the advent of ultra-bright LEDs, some industrial stroboscopes were made using them – and in fact SILICON CHIP described such a strobe in the August 2008 issue. However, it's definitely not for party use – while bright, the white LEDs used are nowhere near bright enough to light a scene.

Several readers have also submitted LED-based indus-

Here's the Power Supply box, shown from the back with the mains input (fused IEC connector) on the left and the 24VAC output socket on the right. The power switch is on the front.



The assembled PCB mounted on the rear of the floodlight assembly. The pot and operate switch emerge through the cover, as shown in the photo below. The two LEDs (between the pot and switch) could also poke through the cover if you were so inclined – obviously, they would need to be mounted with more lead length than is seen here and suitable holes would need to be drilled in the case cover. Note that this PCB is a prototype; there are some minor differences between it and the final board which now has a snap-off section to suit the jiffy box used in the Hot Wire Cutter.

trial strobes over the years for our "Circuit Notebook" pages; for example June 2007 and April 2004 issues. Again, they are for non-entertainment use only.

Photograhic strobes

Talk to a photographer and he'll tell you that strobes are those large studio flashes which are "synched" to the camera shutter. Almost invariably, they do not flash more than once. If you want second and subsequent flashes, you must fire the camera again.

These are NOT the type of strobes we are talking about here – in fact, describing a studio flash as a strobe is a corruption of the word because strobing, the effect, implies movement/rotation. By the way, the word comes from the Greek "strobos" meaning act of whirling.

Using ultra-bright LEDs

Readers will recall two LED array floodlights published in SILICON CHIP. A 10W model was described in February 2012 and a 20W in November of the same year. At the time, we marvelled at how bright these new LED arrays were. But a year is a long time in electronics and now 50W and 100W LED arrays are becoming quite common.

Power

The LED arrays which we tried for this project – 10W, 20W, 50W and 100W – all share a common supply voltage, 30-32V DC. The current varies according to the power; a 10W LED needs only about 350mA while the 100W needs in excess of 3A.

30-32V DC might sound like a difficult voltage to obtain but it is easy. There are many transformers around offering 2 x 12VAC secondaries. Connect them in series and you have 24VAC or thereabouts.

And here's a side-on shot of the business end. The PCB, containing all the driving circuitry, is in the box on top with the speed pot and "operate" switch emerging from the end.

If you remember your bridge rectifier theory, the open circuit (ie, peak) DC output equals AC input voltage, multiplied by 1.414 (the square root of 2), less the voltage drop across the pair of diodes in the bridge (theoretically about 0.6V each or 1.2V) but probably a little more, especially at 1A or so). Let's call it about 2V.

Putting that into a formula, we get (24V – 2V) x 1.414 = 31V!

We can convert that to a reasonably steady DC (the LED will still be happy if it's not perfectly smooth) by placing an electrolytic capacitor across the output and end up with something around 31 or 32V DC.

By the way, if you wanted to make a 100W LED floodlight using one of these LED arrays and this transformer, that is precisely what you'd do.

Making it flash

So we have a high power LED and we have a suitable DC power supply – making it flash should be dead easy, right? Well it is, but . . .

As we mentioned above, getting the flash on-period right is just as important as getting the flash frequency.

Just to reiterate, the frequency is the number of times it flashes per second; the on-period is the length of time the LED is actually turned on.

So we needed a circuit which could adjust both of these paramteters – at least during setup (the frequency should be externally adjustable).

As we mentioned earlier, because it's for entertainment use, it doesn't have to be super accurate.

Beat triggering

In the past, we've seen some strobes which offered "beat triggering" to music – basically a cross between a strobe and a Musicolor.

To be frank, we could never quite see the point – one of the features of a strobe is its consistency of flash, which beat triggering effectively defeats. So we left this one well alone.

If you want something that flashes lights in time with music, build one of the Musicolor projects we've featured! (DSP Musicolor, June-August 2008; LED Musicolor, October-November 2012 and even the Digital Lighting Controller, October 2010).

Believe it or not, the DSP Musicolor also features a "strobe" mode, which can trigger with the beat or trigger by itself but the effect is not as good us-

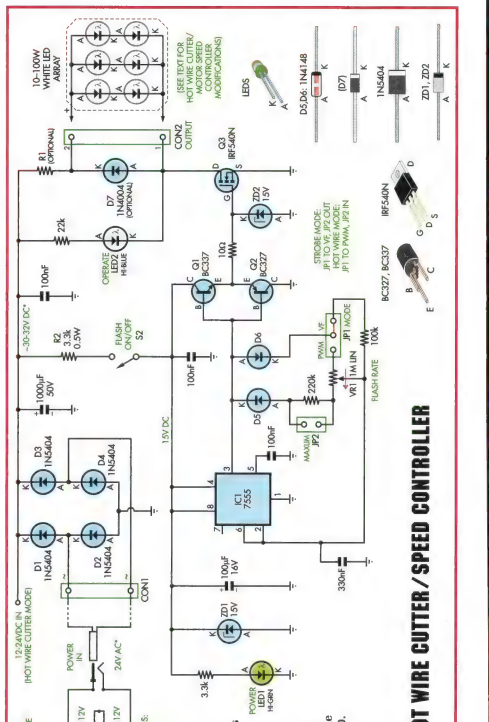


Fig.1: the circuit is shown as one complete device, even though it is constructed in two sections. At left is the power supply, built into its own box, while the balance of the circuit is built on a single PCB, mounted on the rear of the floodlight housing. The circuit as shown suits the LED party strobe but with the addition of just a few components (see text) it also suits the Hot Wire Cutter and JP2 also suits the Electronic Speed Controller, November 2010. It could also be used as a low-power DC motor speed controller.

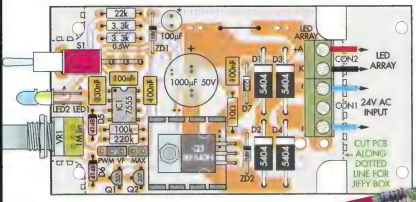
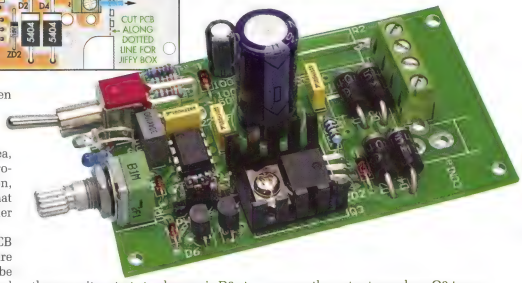


Fig.2: the PCB component overlay. The board may be used as shown for the LED Party Strobe or cut along the dotted line to suit the Jiffy Box used in the Hot Wire Cutter. The photo below is of an early prototype; there are a few minor changes to the final board shown at left, which now has a snap-off section.



ing incandescent bulbs with their even longer filament persistence.

We already have a circuit!

While experimenting with this idea, we recalled an earlier SILICON CHIP project which, with a slight modification, could do exactly what we wanted. That was for our Hot Wire Cutter Controller (December 2010).

We could then make a single PCB which could be used as a Hot Wire Cutter controller OR as a LED Strobe flasher (and even a DC motor speed controller if you wished!).

The circuit is shown in Fig.1.

How it works (strobe mode)

The two 12VAC secondaries of transformer T1 connect in series to Con1 which results in 24VAC being applied to the bridge rectifier (D1-D4). The resultant pulsating DC is smoothed with the 1000µF capacitor following, so a relatively smooth 31V DC supply rail is permanently available for the LED array.

Because the 7555 has a maximum supply voltage of 18V, a low-voltage (15V DC) rail is provided via the 3.3kΩ resistor, 15V zener diode ZD1 and the 100µF electrolytic capacitor following. LED1 shows that power is applied.

A 7555 (CMOS version of the ubiquitous 555 timer) is the heart of the circuit but its connections are a little unusual. Normally pin 7 (discharge) is connected to the supply via a suitable resistor or pot and this is then connected to pins 2 and 6, which in turn connect to the timing capacitor.

In our case, pin 7 is not connected while pins 2 and 6, with the timing capacitor, are connected to the output (pin 3) via potentiometer VR1 and diodes D5 and D6.

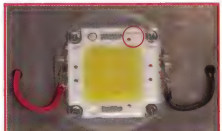
The timing capacitor is initially discharged so the 7555 output will be high. Ignoring Q1 and Q2 for a moment, the capacitor starts to charge via D6 at a rate set by the 100kΩ resistor. When its voltage reaches 2/3 of the supply voltage, threshold input pin 6 detects this and sends the output low. This in turn discharges the capacitor via the potentiometer and D5. When its voltage reaches 1/3 supply, pin 2 (the trigger) forces the output high again and the whole process continues.

Due to the combination of VR1 and the 100kΩ and 220kΩ resistors, D5 and D6 cause an unequal charge/discharge rate so that the output high time is very much shorter than the output low time. When the output is high, transistor Q1 turns on, charging the gate of Mosfet Q3 and causing it to turn on, in turn, briefly lighting the LED array (and LED2). As soon as the output goes low, Q2 turns on, discharging the gate of the Mosfet ensuring it is fully turned off.

We neglected to mention the power switch S1: because the LED array (or hot wire element) is totally under the control of the circuit, there's no need to provide a high-current power switch.

S1 switches power to the oscillator/Mosfet and when it's off, it's off! However, there may be times when you want to "remotely control" the strobe, say when it is mounted up high for best effect and the supply is down low.

For this reason, we have shown a mains-rated switch on the transformer primary – if you don't think you need this (eg, you can turn it on and off at a power point), simply wire the transformer direct to the IEC socket.



The LED array mounted on the floodlight housing. Ringed in red – and very hard to see even in good lighting – is the "+" symbol (anode). It's a bit misleading because this is not closest to the LED anode but this is the way it goes: the red wire is the anode, the black wire the cathode.

How it works (hot wire cutter/speed controller mode):

When JP2 is inserted and JP1 is moved to the left side of its header set, rather than controlling the frequency, VR1 adjusts the duty cycle while the frequency remains fixed. That's because as the wiper of VR1 moves, it increases the on-time by the same amount that it decreases the off-time (or vice versa).

This is more suitable for the hot wire cutter and can also be used as a low-voltage DC motor speed controller, such as featured in November 2008 and

November 2010. Therefore the one PCB can serve a number of purposes.

We should point out that the low operating frequency would give quite a "pulsy" operation if used for either alternative application but if this is easily fixed by reducing the value of the capacitor on pins 2 & 6 of IC1 (to, say, 10nF).

Construction

We decided to use the same floodlight housing/reflector assembly which we used for the 20W LED floodlight project. Both of these are available from Oatley Electronics, along with a 12V+12V 200W toroidal transformer which is perfect for the job. The housing we used suits the 20W, 50W and 100W LED arrays.

The advantage of the floodlight housing is that the front is pre-drilled to take the LED array and the back end has four mounting pillars perfect for mounting the PCB.

With the exception of the mains components and transformer, which we'll get to in a moment, all components (apart from the LED array) are mounted on a single PCB, coded 16101141 and measuring 95 x 49.5mm.

Because we made the PCB suitable for either the Party Strobe or the Hot Wire Cutter (which has a slightly smaller zippy box) the board has a snap-off section. Left intact, the mounting holes to suit the floodlight housing; with the section removed, it fits in a zippy box.

Start assembly with the controller PCB. First are the small resistors – there are only five to mount, then the larger 0.5W 3.3kΩ resistor. The resistor shown as R1 on the circuit and PCB overlay can be replaced with a wire link for the Strobe.

Next are the the eight diodes (watch both their polarity and type – the two smaller diodes are zeners) and then the five capacitors (watch the electrolytic polarity).

We solder the indicator LEDs directly to the PCB because they are really only needed during setup.

Because the LED array is so bright, it makes sense to leave it disconnected until the very last thing (otherwise the blinding flash will . . . blind you!) and the power LED is somewhat redundant once the Party Strobe is completed because you know it's working by the LED array flashing! Make sure the LED anodes (longer lead) go into the holes marked "A".

If you wished, you could have these LEDs emerge from the case by leaving extra long leads and drilling suitable holes in the case.

Both of these components were included more for the Hot Wire Cutter application because you cannot normally see any operation (and you don't really want to test that it's on by touching the wire!).

The last components to be placed before the hardware are transistors Q1 & Q2, Mosfet Q3 and IC1, the 7555 timer.

The Mosfet is mounted on a U-shaped heatsink, itself held in place by the Mosfet mounting screw. Place the Mosfet in position with the gate, drain and source in their appropriate holes (G, D and S) but don't solder them yet. Bend the Mosfet down 90°so that its hole lines up with the hole in the PCB. Slip the heatsink under it and place an M3, 6mm screw through the Mosfet, heatsink and PCB and secure with a nut on the PCB side. Now you can solder the legs in position.

There are arguments for and against using a socket for the 7555 timer – we prefer to solder them directly in place. Either way, ensure the chip or socket is mounted with its notch towards the top.

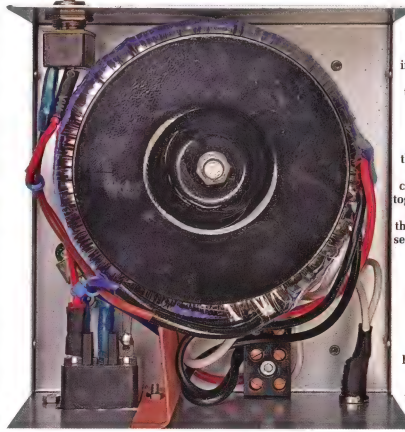
Finally, mount the hardware (two header pin assemblies, two terminal blocks, DC input socket [if needed], power switch and speed potentiometer). The pot mounts side-on to the PCB so its shaft can emerge through the side of the floodlight housing or jiffy box.

Housing and wiring the transformer

For both convenience and safety, the transformer needs to be mounted in some form of sturdy box or case. The specified transformer measures 110mm (diam) x 50mm high, so the case will need to be at least that big.

We used a small folded aluminium case from Jaycar (Cat HB5444) which has plenty of room for the transformer, IEC input socket, switch and fuseholder.

The Oatley transformer comes with 4.8mm female spade connectors for both the blue and brown primary wires while the two secondaries (red & black, and black & white wires), each have



There's not a lot of room in the Power Supply Box. It houses the 12V+12V toroidal transformer, the IEC mains input socket (with fuse-holder), the 2.5mm output socket, power switch and the three-way terminal block (the middle terminals connect the two windings together). Note the sheet of fibre insulation between the mains and low voltage sections plus the cable ties – just in case something comes loose. And all of the "bitey bits" are covered with heatshrink tubing (along with the exposed 24V output socket) – again, just in case. Incidentally, we had to cut the end off the transformer mounting bolt to allow it to fit below the top of the box.

6.5mm spade connectors.

Probably the easiest and safest way to connect the transformer is to mount a chassis-mounting IEC male connector in the box, because it has 4.8mm spade lugs on the back.

The type we used has an integrated fuseholder, even though the transformer has a self-resetting thermal fuse, a supply of this type could do quite a bit of damage before that fuse trips.

We secured a 70 x 40mm L-shaped piece of fibre insulation under one of the IEC socket nuts to act as a barrier between the mains and low voltage sections of the supply.

Second power switch

As we mentioned earlier, a power switch is not really needed on the transformer box but it could be handy if you want to mount the Party Strobe up high and run it from the power supply down low. So we fitted a mains-rated power switch as well.

It is essential that the metal box is earthed back to the mains earth (ie, via the 4.8mm male earth lug on the IEC connector). The earth wire must securely connect to the case via a crimped lug held in place by a suitable screw, nut and shakeproof washer.

Even if mounted in a plastic box, the main bolt holding the transformer in place must be similarly earthed because this bolt can be touched from outside the box.

It was easiest to cut the spade connectors off the secondary wires and secure them in a terminal block. The secondaries are connected in series – the two black wires are joined (but don't connect to anything else) while the 24VAC is taken from the red and white wires.

Because we are only dealing with low voltage and reasonably low current, the cable from the power supply box to the Party Strobe itself could be figure-8 or a similar gauge 2-wire lead. Length shouldn't be a major problem – we'd suggest 10m or so should be fine.

Note that we have a 2-way terminal block for AC input on our prototype but the final version has a 3-way terminal with the centre unused, so you can join the transformer secondaries here if you wish.

Do not be tempted to use mains lead (ie, brown, blue and green/yellow) for the inter-connection – mains lead should be used for mains and nothing else.

Parts list – LED Party Strobe

1 double-sided PCB, coded 16101141, 95 x 49.5mm
1 SPDT PCB-mount right-angle toggle switch (S1) (eg, Altronics S1320)
1 medium sized LED floodlight housing (Oatley Electronics).
1 3-way terminal block (CON1)
1 2-way terminal block (CON2)
1 PCB-mount DC socket (optional; replaces CON1)
1 3-way pin header (JP1) with 2-pin shorting block
1 2-way pin header (JP2) with 2-pin shorting block
1 6073B-style heatsink
4 M3 x 6mm machine screws and nuts
1 short length tinned copper wire
1 knob to suit VR1

Semiconductors
1 7555 CMOS timer (IC1)
1 BC337 NPN transistor (Q1)
1 BC327 PNP transistor (Q2)
1 IRF540N Mosfet (Q3)
1 high-brightness white LED array, 20-100W (eg Oatley Electronics 100W)
1 3mm green high-brightness LED (LED1)
1 3mm blue LED (LED2)
4 1N5404 3A diodes (D1-D4)
2 1N4148 signal diodes (D5,D6)
1 1N4004 1A diode (D7) (optional, for motor speed control)
2 15V 1W Zener diodes (ZD1,ZD2)

Capacitors
1 1000μF 50V electrolytic
1 100μF 25V electrolytic
1 330nF MKT *(code 334, 330n or 0.33μF)*
3 100nF MKT *(code 104, 100n or 0.1μF)*

Resistors (0.25W, 1% unless otherwise stated)
1 220kΩ *(code red red yellow brown or red red black orange brown)*
1 100kΩ *(code brown black yellow brown or brown black black orange brown)*
1 22kΩ *(code red red orange brown or red red black red brown)*
2 3.3kΩ 0.5W *(code orange orange red brown or orange orange black brown brown)*
1 10Ω *(code brown black black brown or brown black black gold brown)*
1 1MΩ linear 9mm potentiometer (VR1)

Power Supply box

1 200VA toroidal transformer, secondaries 12V + 12V with mounting hardware
1 aluminium or steel box, at least 120 x 150 x 60mm (eg Jaycar HB-5444)
1 IEC mains lead
1 IEC male chassis-mounting mains socket with integrated M205 fuseholder
1 2A M205 slow-blow fuse
1 3-way terminal block
1 mains-rated panel mounting SPST power switch, min 3A contacts
1 2.5mm DC power socket, chassis-mounting
1 2.5mm DC power plug
1 length (to suit) figure-8 or other 2-wire cable (supply to strobe head)
1 100mm length heavy duty hookup wire fitted with 4.8mm insulated female spade connectors
1 50mm length earth wire (green or green/gold) fitted with 4.8mm female spade connector one end and 5mm crimped earth lug (box earth lead) the other
1 M4 x 20mm screw with two nuts and star washer (box earth)
3 M3 x 10mm screws with nuts
1 70 x 40mm fibre insulation sheet (eg Elephantide) bent into "L" shape
2 cable ties (to secure mains wiring)
Heatshrink tube scraps to cover the "bitey bits"

Warning: Possible Epilepsy Trigger

Back in the early days of strobes, considerable research was undertaken when it was found that some people suffered epileptic episodes with flashing lights.

It's called photosensitive epilepsy.

Usually, the people affected were those who had some pre-disposition to epilepsy. Unfortunately, some had no idea that they were in the danger group. Fortunately, these days much more is known about the disorder and most people are on some form of drug regimen to control attacks.

Not all people suffering from epilepsy will suffer photosensitive epilepsy – apparently, it's only about one in twenty or even less.

And it's not just strobe lights which cause it: back in 1997, the game "Pokemon" caused a sudden spike in episodes when they brought out a game which flashed! It can also be caused by many other forms of repititon – even driving past a paling fence, for instance!

Most people in the danger group will already know about it and make sure they don't subject themselves to triggers. Tightly shutting and covering the eyes is a good "first line of defence".

But when using the LED Party Strobe, if you find that anyone suffers from either an epileptic episode, or partially or completely feints, feels disoriented, giddy or generally unwell, turn the strobe off and ensure that the person is taken outside the sphere of influence (ie, where flashes cannot be seen, even at a distance) before any further use.

In the event of a full seizure, treat as you would for any epileptic episode:

Stay calm

Prevent injury. During the seizure, you should exercise your common sense by insuring there is nothing within reach that could harm the person if he or she struck it.
Pay attention to the length of the seizure.
Make the person as comfortable as possible.
Keep onlookers away – gawkers and do-gooders are definitely not welcome!
Do not hold the person down. If the person having a seizure thrashes around there is no need for you to restrain them. Remember to consider your safety as well.
Do not put anything in the person's mouth. Contrary to popular belief, a person having a seizure is incapable of swallowing their tongue so you can breathe easy in the knowledge that you do not have to stick your fingers into the mouth of someone in this condition. They are more than capable of biting down hard on your fingers.
Do not give the person water, medication or food until fully alert.
If the seizure continues for longer than five minutes, call 000.
Be sensitive and supportive, and ask others to do the same.

Just one point to keep in mind: it won't affect operation, but one side of the 24V AC mains is earthed via the case. (This only normally matters if you want to take scope imates).

Testing

First check the output from your transformer box – it should be around 24VAC. If it is zero, you've made a mistake somewhere (eg, connected the two transformer windings out of phase) or perhaps you've blown the fuse in the IEC connector. You did put a 5A M205 fuse in the IEC connector, didn't you?!!!

At the head end, check your component placement, polarity and soldering and if everything is correct, connect the 24VAC from your transformer, with S2 (the operate switch) off and both jumper shunts off. With S1 on, you should have around 30-32V DC between the cathodes of D1/D2 and the anodes of D3/D4.

Now turn S2 on and check that LED1 lights and that you have 15V DC between pins 8 and 1 of IC1 (or between the collectors of Q1 and Q2).

If all checks out correctly, place one jumper shunt across the "VF" (variable frequency) pair of JP1 (leave the other shunt off) and you should also find that you have quick flashes from LED2, with the rate varying as you vary the potentiometer (VR1)

Now all that's left is to switch it off, connect the LED array to CON2 (anode to top) and briefly switch on to prove it works! Don't look directly at the LED array, nor leave it running for more than, say, a second because the LED array needs to be mounted on a heatsink.

Incidentally, if you get the connections to the LED array back to front, you won't do any harm.

Mounting in the floodlight enclosure

Solder wires to the LED array as shown, determining which is the anode (+) and which is the cathode (-) from our photos.

There are six holes drilled in the front of the enclosure. Four are tapped (M3) and suit the LED array while the other two are to pass the wires through to the back.

First apply a generous dollop of heatsink compound to the back of the LED array and then screw it in position using the M3 4-6mm screws supplied. Make sure the LED array is tight down on the surface.

Feed the two wires through the other holes and turn the enclosure over. Mount the PCB on the four tapped pillars provided and connect the wires from the LED array to CON2 (shorten them as required). For the moment, connect your 24VAC supply wires to CON1 and switch on. OK, it all works.

Now we need to drill a hole in the enclosure rear cover to suit the potentiometer shaft. Mark the position on the cover as accurately as possible and drill this out to suit the pot shaft (usually about 6-7mm).

There is already a hole in the cover for the power wires to enter – indeed, the box should also contain a gland to help keep it watertight.

Finally, disconnect power again and connect the LED array wires to their respective positions on CON2.

Finishing off

Fit the reflector to the front of the housing with the screws provided and remove the protective film. Then screw the glass cover to the housing, making sure you first put the seal underneath it.

Similarly, fit the cover to the back of the housing (ie, over your PCB) again with its seal. Place the knob on the shaft and your Party Strobe is ready to use.

One warning: don't touch the LED array. It gets hot – and the oil on your skin probably won't do it a great deal of good! SC

The LED array, housing and 200VA 12V+12V toroidal transformer used in this project all came from Oatley Electronics – www.oatleyelectronics.com

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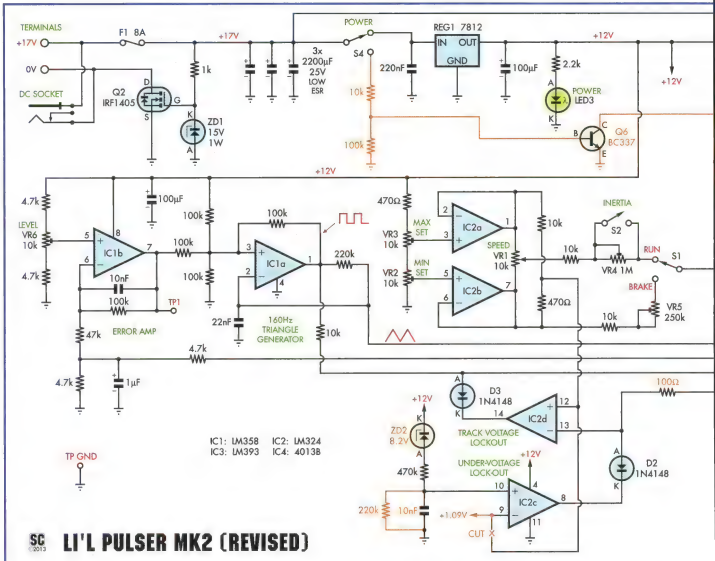


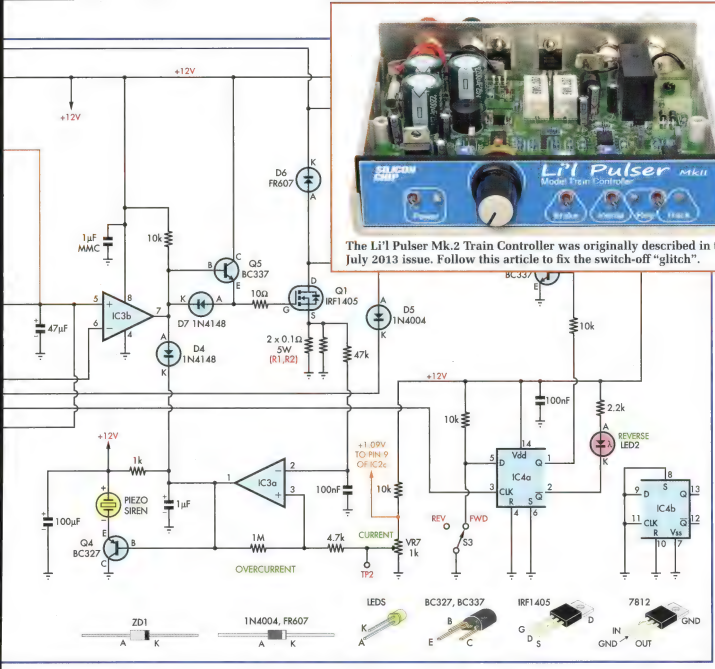
SC 2013 **LI'L PULSER MK2 (REVISED)**

Fig.1: this circuit diagram shows the required changes to the original Li'l Pulser Mk.2 circuit in orange. Note that Q6 and its associated base divider resistors are only added as a 'belts and braces' measure if you are building the revised PCB (see text & Fig.3).

Li'l Pulser Mk2: fixing the switch-off lurch

By NICHOLAS VINEN

Our new Li'l Pulser Model Train Controller, described in the July 2013 issue, has been very popular but a design flaw has become apparent. At switch-off, any locomotive(s) on the track can suddenly lurch forward, even if they are stationary at the time. This is regardless of the position of the speed control knob and the brake switch. Here's the cure.



The Li'l Pulser Mk.2 Train Controller was originally described in the July 2013 issue. Follow this article to fix the switch-off "glitch".

IF YOU'VE BUILT the Li'l Pulser Mk.2, then you'll want to fix the switch-off flaw. The magnitude of the effect varies, depending on how the unit is switched off (via its front panel controls or the mains power supply), what type of supply is being used, the types of locos involved and so on. It can range from a minor issue to one serious enough to cause derailment.

While this can be solved by taking the locos off the track or disconnecting the controller from the track before switching it off, that's inconvenient. So we set about figuring out why this was happening and how to fix it.

The cause

Take a look now at the circuit of Fig.1. This shows the relevant sections of the original circuit published in the July 2013 issue but with a number of changes shown in orange.

Ignore the changes for the moment while we discuss the problem and how it occurs. Comparator IC3b generates the PWM waveform to drive Mosfet Q1, which switches the supply voltage to the tracks, controlling how much power the locos receive. This works by comparing a 160Hz triangle waveform to a control voltage, with the control voltage indicating the desired loco speed; the higher the control voltage, the higher the output PWM duty cycle and thus the higher the motor speed.

The control voltage is low-pass filtered by an RC network, to prevent it from changing too rapidly and also to simulate train inertia. The amount of filtering applied depends on whether or not the inertia switch is on and the position of inertia control pot VR4 but regardless, there is always some filtering of this signal.

When the unit is switched off and its power supply capacitors discharge, the power supply to the op amp generating the triangle signal collapses and so the triangle signal's voltage drops rapidly. But this filtering of the control signal causes the control voltage to drop much more slowly. In other words, the 47µF capacitor at pin 5 of comparator IC3b remains charged for some time after power is removed.

This means that at switch-off, the

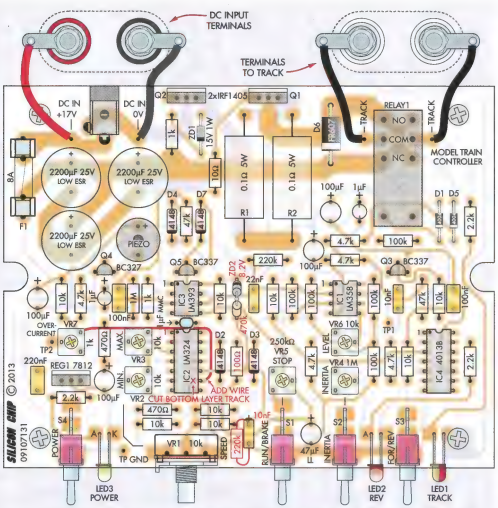


Fig.2: here's how to make the changes to the original PCB to eliminate the switch-off lurch. The changes are all indicated in red and are easy to do (see text).

control voltage rises relative to the triangle waveform (by dint of the triangle voltage dropping) and so the PWM duty cycle increases until it reaches 100%. It stays at 100% until the power supply has collapsed to the point where there is no longer sufficient voltage to turn the Mosfet on, at around 3-4V. This can take a significant fraction of a second.

During that time, the full input supply voltage, typically around 17V, is applied across the tracks. Hence the sudden jerk from the locomotive(s).

This can happen regardless as to whether the Li'l Pulser's power switch (S4) is thrown or its power supply is turned off at the mains outlet but it tends to be worse when switched off via S4. That's because if the supply is switched off at the wall, the Li'l Pulser's input capacitors remain in parallel with its output capacitors and so the supply voltage drops more slowly. Depending on that amount of capacitance, the supply voltage may drop slowly enough that the control voltage drops as fast or faster, preventing any output pulses.

The solution

We have taken a two-pronged approach to solving this. The first set of modifications pretty much eliminates the jerking and can be easily applied to existing PCBs. We have also produced a revised PCB which incorporates these changes and will supply this to new constructors. The revised board also incorporates a few extra components which provide further protection against a switch-off pulse when power is switched via S4, which as described above, tends to be the worst case.

These circuit changes are shown in orange on Fig.1, as noted above. First, we have taken the power-up reset circuit, based around op amp IC2c and converted it into an under-voltage lock-out, which still also performs the original reset function although by a different means.

Originally, an RC filter from the 12V rail, connected to pin 10 of IC2c, provided a time delay. This was compared against a reference voltage at pin 9, which was derived from the outputs of the min/max speed buffer op amps IC2a & IC2b. This is the same reference voltage used by op amp IC2d (at pin 12) to time the switch-over of the reversing relay.

In operation, some time after power-on, reset is asserted and Mosfet Q1 is held off until the capacitor at pin 10 charges to a higher voltage than the reference. The reset is then released and normal operation begins.

For the new circuit, we drastically reduced that capacitor value from 10µF to 10nF, effectively eliminating the time delay. Instead, 8.2V zener diode ZD2 plus the voltage divider formed by the 470kΩ resistor and an additional 220kΩ resistor prevent the reset from being released until the power supply voltage has risen past about 11V. This takes some time (for the supply capacitors to charge, etc) so despite the much smaller capacitor value, there is still a reset delay at start-up.

This 11V threshold must be reasonably accurate; it has to be below the minimum supply voltage, or else reset will not be released at power-up. At the same time, it can't be too far below the supply voltage as we want reset to occur shortly after switch-off, before any unwanted output pulses can be delivered to the tracks.

To this end, we have changed the reset reference voltage from one which varies depending on the positions of VR2 and VR3 to a fixed 1.09V (nominal) derived from an existing divider across the 12V rail (10kΩ/1kΩ). Pin 10 must rise above this voltage in order for the reset to be released and since the 470kΩ and 220kΩ resistors form a roughly 2:1 divider, that sets the threshold at 8.2V + 1.09V x (470kΩ + 220kΩ) ÷ 220kΩ = 11.6V.

In practice, at the low current it is being operated, ZD2 will be at the lower end of its breakdown voltage range, so the actual threshold will tend to be closer to 11V. The minimum output of REG1 is 11.4V but also consider that the 1.09V reference is derived from the supply voltage and so the threshold

Extra Parts For PCB Modifications

1 8.2V zener diode (ZD2)
1 10nF MKT capacitor
1 470kΩ 0.25W resistor
1 220kΩ 0.25W resistor
1 100Ω 0.25W resistor
1 short length light duty hook-up wire

Parts List Changes For Revised PCB

Additional parts
1 BC337 NPN transistor (Q6)
1 8.2V zener diode (ZD2)
1 10nF MKT capacitor
1 220kΩ 0.25W resistor
1 100kΩ 0.25W resistor
1 10kΩ 0.25W resistor
1 100Ω 0.25W resistor

Deleted part
1 10µF electrolytic capacitor

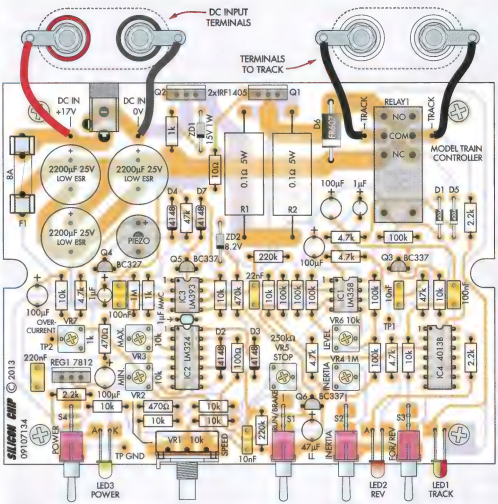


Fig.3: follow this parts layout diagram if you're building a new unit using the revised PCB (09107134). This version also adds transistor Q6 and two associated resistors.

drops somewhat if the supply is on the low side.

Now since the 10nF capacitor only provides a very short delay (with a time constant of 10ms) and with a threshold of about 11V, once the unit is switched off, the 12V supply doesn't have to drop by much before it enters the reset state which forces Q1 to stay off while the supply voltage decays to zero.

Making the changes

We made these changes to our prototype and it no longer causes any noticeable motor pulse at switch-off. Fig.2 shows what is required. Start by removing the 470kΩ resistor to the right of IC3, the 10kΩ resistor directly below it and the 10µF electrolytic capacitor to the left of S1.

Since it's a double-sided board, it has plated through-holes so the easiest way to remove the resistors is to clip their leads off close to the body, then pull the stubs out with pliers while heating the solder joints. The holes can then be cleared with a solder sucker. The electro can be rocked out while heating the pads and gently pushing on the body and its mounting holes cleared of solder too.

Next, cut the track to pin 9 of IC2, on the underside of the board (shown in Fig.2 with a red 'x'). Fit a fresh 470kΩ resistor and ZD2 to the pads originally used for the 470kΩ resistor, with the cathode of ZD2 to the top of the board and 'air wire' them together. The 100Ω resistor and 10nF capacitor can be fitted as usual, with the added 220kΩ resistor wired across the new capacitor under the board.

Finally, run a short length of insulated wire (eg, Bell wire or Kynar) under the board, from the now-isolated pin 9 of IC2 to the top-most pad of VR7.

When you reassemble and test the unit, you should find that it now operates as before but without the switch-off pulse from the motor(s). If the unit fails to operate, check the voltages at pins 9 & 10 of IC2. Pin 10 should have a slightly higher voltage when power is applied; it's unlikely that it won't but if not, you may need to change ZD2 to the next lowest voltage (eg, 7.5V).

New PCB & further changes

To make it easier for new constructors, we can now supply a revised PCB for the Li'l Pulser, incorporating all the modifications. This new PCB is coded 09107134 and is available via the Silicon Chip Online Shop.

Fig.3 shows the overlay diagram for the revised PCB. You will need to refer to the original assembly notes in the July 2013 issue when building it.

In addition to the above changes, we have also added NPN transistor Q6 and two more resistors so that as soon as S4 is switched to the off position, Q6 turns on and rapidly discharges the 47µF control voltage filter capacitor, so there is no possibility of an output pulse regardless of how quickly the under-voltage lock-out circuit kicks in.

This is a bit of a 'belts and braces' approach, ie, it isn't totally necessary but it provides some extra cheap insurance against any sort of output pulse being delivered to the tracks.

With these changes the unit will now behave itself at switch-off but otherwise operate identically. SC

ALTRONICS

Build It Yourself Electronics Centre Issue: Jan 2014

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X 0680

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Size shown for illustration purposes.

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Type	Part	ea
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10W 240V AC (115 x 135 x 84mm)	X 2312	$42.50
20W 240V AC (182 x 158 x 105mm)	X 2314	$78.95
20W 12V DC (182 x 158 x 105mm)	X 2316	$59.95
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40W (12V)	N 0040C	$159	$125
60W (12V)	N 0060C	$199	$149
80W (12V)	N 0080C	$245	$195
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120W (24V)	N 0124	$399	$299
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With pass through 240V socket so you don't lose an outlet! Great for keeping your phone, tablet or MP3 player charged.

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This wireless home energy monitor can log power usage on mains outlets around the house. Includes channel 1 plug in sensor & base station. Extra sensors sold separately. 30m range. Displays usage in kW/h or $. Requires 3xAA batteries.

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High current design with 3.5A output! Ideal for simultaneous tablet & phone charging. Mains surge circuitry protects your expensive appliances from damaging spikes/surges.

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Old power supply kaput? No problem! Fitted with dual USB outputs. Includes mains lead & 8 tips to suit most laptops. Selectable voltages (15-24VDC), max 6A/100W.

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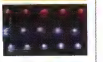
Warm White	X 2553B	$34.95	$17
Blue	X 2554A	$19.95	$9.95
White	X 2555A	$26.95	$13



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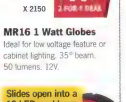

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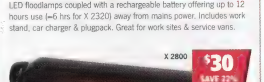

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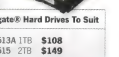
4 Channel H.264 recording | Weatherproof cameras | Live smartphone viewing | Motion triggering



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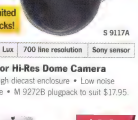

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0 Lux | 420 line resolution | 20m IR Range

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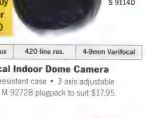

0.0005 Lux | 420 line res. | 4-9mm Varifocal

Vari-Focal Indoor Dome Camera
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0 lux | 420 line resolution | 4-9mm focal adj.

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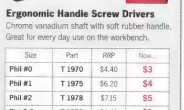

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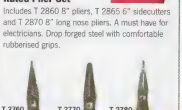
Flat 5mm	T 1955	$6.20	$4
Flat 6mm	T 1958	$7.15	$5



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Salt Water Powered Buggy Kit

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Line Tracking Mouse Kit

Much like the robot (left), this mouse is designed to track along black lines on a table top or floor. Full assembly ≈1hr. Ages 6+. Requires 2xAA batteries

6 In 1 Solar Power Fun Kit

A great way to learn about electronics and solar power. Each kit can be assembled into one of 6 devices - windmill, hover craft, airboat, revolving plane, car and puppy (main picture).

'Follow Me' Robot Kit

Uses four inbuilt microphones to detect sound (such as a hand clap) and moves toward it. Ages 8+. No soldering required. Requires 4 x AAA batteries (not included).

Creepy Spider Powered By Salt Water!

This creepy crawly spider uses a salt water fuel cell to power its legs. Just add some salt water to the cell plate & the spider will creep around. No batteries required! Ages 8+.

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B 6061

CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

Pseudo-random timer for a bird scarer

This circuit is designed to trigger a gas cannon to scare birds and bats away from crops. The period between cannon firings must vary or else the flying creatures will learn to avoid it. It was decided that the cannon firings must have a minimum interval of 10 minutes and a maximum of one hour. This circuit (Fig.1) cycles through 10 different periods which are preset using resistors.

It's based around the voltage controlled oscillator (VCO) section of CMOS PLL chip IC1 (4046B) plus decade counter IC2 (4017B). At power-up, the MR pin of IC2 is pulled high and so the counter is reset. In this state, output O0 (pin 3) is high while the other outputs are low. This means that D6 is forward-biased and so current can flow through R1, which is normally 100kΩ (as explained later).

This forms a voltage divider with the lower 100kΩ resistor which is filtered by a 1nF capacitor and the resulting voltage (about 5.5V) is applied to pin 9 of IC1. This is the VCO control input and so determines the oscillator frequency.

Other components which affect the frequency are the 1μF capacitor between the C1a and C1b pins and the resistance from pin 11 (R1) to ground. VR1 is adjusted so that with R1 = 100kΩ, the VCO output at pin 4 is 1Hz. This is buffered by NPN transistor Q1 to flash the running LED (LED1) to indicate that the circuit is operational.

It's also fed into CMOS 14-stage ripple carry counter IC4 (4020B). Its O11 output (pin 1) goes high after 2^{11} (2048) clocks which, with an input rate of 1Hz, is after around 35 minutes (ie, 2048 ÷ 60 seconds).

When this output goes high, the pulse is coupled to input 9 of IC3d, one section of a Schmitt-trigger inverter. It's AC-coupled via a capacitor to give a brief pulse and the output of the inverter's low excursion triggers 555 timer IC5 which energises relay RLY1 for five seconds (adjusted using trimpot VR2).

This is the charge time for the gas cannon and when the relay contacts open, the cannon fires, making a very loud noise! LED2 is lit during the charging period, to warn people who may be working on the unit to cover their ears.

At the same time, this trigger signal is buffered using inverter stages IC3e and IC3f to give a positive pulse at the MR (master reset) input of IC4, so that it starts counting from zero again. This pulse is also applied to clock input CP0 (pin 14) of IC2 and the next output then goes high.

After the first 35-minute period, O1 of IC2 is now high while the other outputs are low and so now R2 determines the voltage at pin 9 of IC1. By selecting a different value from R1, the result is that the VCO runs at a different frequency and so the next period before the cannon fires is different to the last. This period is proportional to the resistor value, so R1-R10 can range from 27kΩ (10 minutes) up to 180kΩ (just over an hour).

The remainder of the circuit is used to set the unit so that it only runs during daylight hours or alternatively, only at night, depending on what type of creature is being attracted to the crop. When light falls on the LDR, its resistance is low and so the output of inverter IC3a is high. Thus, if switch S2 is set in the "night" position, during the day, diode D4 is forward-biased, holding the master reset input of IC4 high and thus preventing it from counting.

The output of IC3a is further inverted by IC3b and so if the switch is in the "day" position, the opposite occurs. In other words, IC4 is held in a reset state at night and allowed to run during the day.

Note that it is suggested that R1 = 100kΩ since that makes calibration easy; at power-up, the output of IC1 should be exactly 1Hz so VR1 can then easily be adjusted with the aid of a frequency counter (built into many DMMs these days).

Merv Thomas,
Balgal Beach, Qld.

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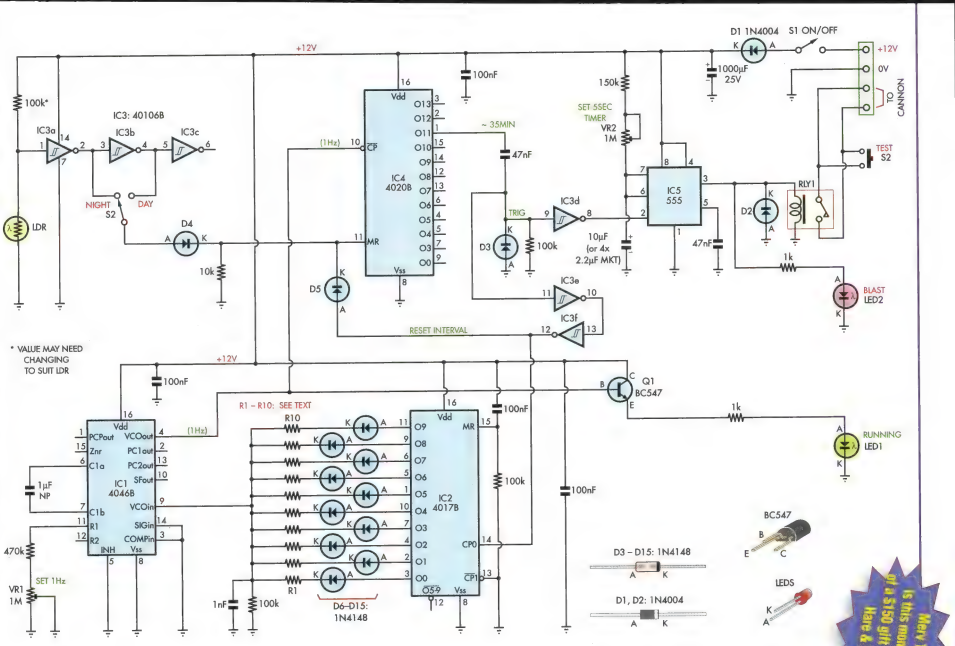

Fig.1: the circuit is based on the VCO in CMOS PLL chip IC1 and also on decade counter IC2 to generate the random cannon firings. IC1 clocks counter IC4 and when its O11 output goes high, it triggers IC5 (via IC3d) which then energises relay RLY1 for five seconds to charge and fire the cannon.

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Merv Thomas

Universal numeric display for controllers running Maximite basic

When using a MiniMaximite as an embedded controller, the need may arise to display the results of measurements or calculations. If these results vary enormously in magnitude, the difficulty of displaying them without loss of precision is a real problem. Currently, the display of choice appears to be something like a 16-character x 2-line LCD panel. With 16 digits to work with, it is relatively easy to display numbers which have a large range.

But the LCD has one drawback and that is readability. Being a relatively small display you have to be quite close to read the small characters and in difficult lighting conditions the display can be hard to read even when close up. I decided that I really needed a bright self-illuminating 7-segment display with large digits that can be easily seen from across the room. Furthermore, the display should be able to display any number that Maximite BASIC can generate, no matter how large or small.

This is no mean feat as Maximite BASIC can generate numbers in floating point form as large as 3.4×10^{38} and as small as 1.2×10^{-38}. In doing so, it can use up to six significant figures for the mantissa. As well as floating point form, some numbers may be expressed in fixed point format (eg, 1234.56) or as an integer (eg, 45678). Again, up to six significant figures may be reported. The negatives of the preceding numbers will also need to be displayed.

To achieve this, the display will need six digits for the mantissa and a further two for the exponent. Additionally, bar LEDs (D1 for the mantissa and D2 for the exponent) are required to display the sign.

Results are displayed either in floating point form (eg, -1.23456^{-12}) or as integers (eg, 23456789). Any number in fixed point format is converted to floating point form for display. This way all six significant figures are retained for all numbers and only one decimal point needs to be controlled.

This latter condition is important because the project is very demanding of outputs, requiring 11 of the 20 available. The unused outputs were spread so that applications had the ability to use ADC inputs (I/O 5-10) or frequency, counting and open collector functions (I/O 11-13).

The 7-segment display digits are 1-inch types (RS Cat. 2358957). These large units actually use two LEDs in series per segment but only one LED for the decimal point. If you build this project using smaller units which use only one LED per segment, such displays will be over-driven and the 10Ω resistors will have to be increased in value.

The voltage drop across the two LEDs in series amounts to more than the 3.3V driving voltage available from the MiniMaximite outputs. Consequently, the MiniMaximite cannot be used to directly drive the display. Instead, BCD-to-7-segment display driver IC1 is employed.

Running IC1 from a 5V source gives just enough output to drive the display. It has the added advantage of only needing four outputs from the MiniMaximite instead of the seven that would be needed if the MiniMaximite had driven the display directly. A 5V supply was chosen because it is a commonly available voltage. (The Maximite, for example, already comes with a 5V output).

The eight digits are multiplexed using outputs 1-3. Again, to save on the number of output pins used, IC2, a 3-to-8 channel multiplexer is used. Multiplexing is achieved using an interrupt via the SETTICK command. This ensures the display is refreshed every 25 milliseconds.

I/O 4 blanks the entire display when taken low.

The decimal point is driven by output 19 and, being part of digit 1, is also multiplexed. The two negative sign LEDs are driven directly by outputs 14 and 20. These are not multiplexed and consequently a higher-value series current-limiting resistor is required to achieve approximately equal brightness with the rest of the display.

The program uses three subroutines – FORMAT, BLANK and ERROR1 – together with the SETTICK interrupt routine called DISPLAY. BLANK does what it suggests and blanks the display. ERROR1 flashes the display if there is an out of range error in the number. (MiniMaximite cannot generate numbers greater than 3.4×10^{38} or smaller than 1.18×10^{-38}). FORMAT puts the number to be displayed in either floating point or integer form and stores the result in the variable, number$. Every 25ms the interrupt routine, DISPLAY, carries out the multiplexing task of displaying the contents of number$.

Your program should occupy the MAIN routine. Any number you wish to display should be stored in the variable 'n' and this should be followed by a call to the subroutine FORMAT. Your number will then appear on the display. In its present form, the MAIN routine just consists of four lines to test the display. At the prompt any number entered will appear on the display. You should remove these four lines and substitute your own program.

The software, 7s238.bas, will be available for download from the Silicon Chip website.

Jack Holliday,
Nathan, Qld. ($60)

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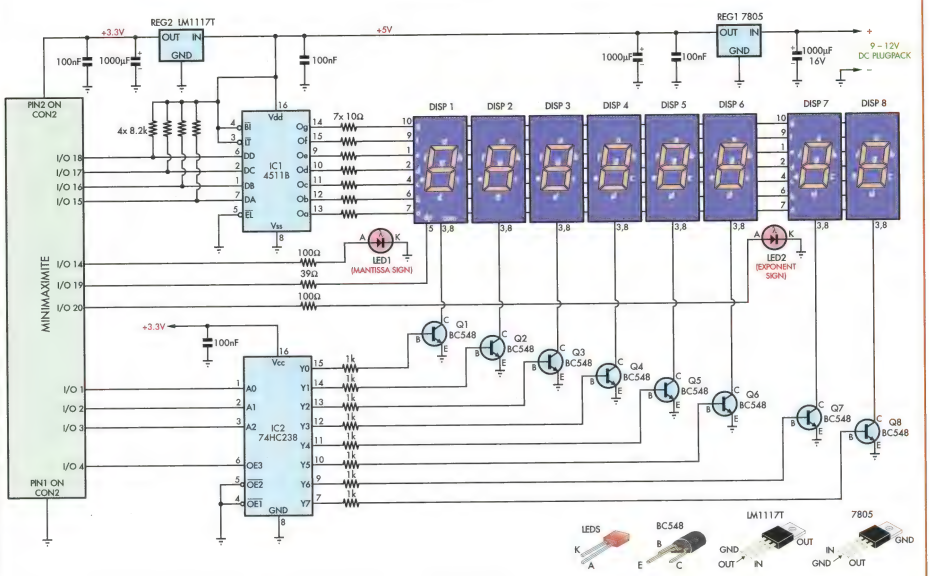
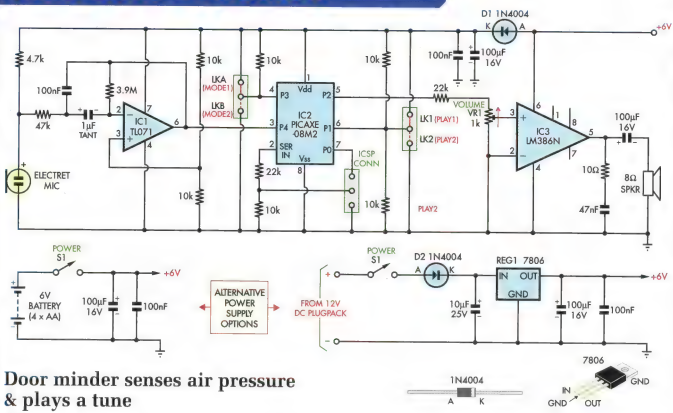


Fig.2: the circuit uses BCD-to-7-segment display driver IC1 to drive the display segments, while 3-to-8 channel multiplexer IC2 multiplexes the display digits.



Door minder senses air pressure & plays a tune

This Musical Door Minder is an alternative to the traditional light beam detector system often used to monitor entrance doors. It sounds an alarm each time someone enters or leaves the room and is triggered by the change in air pressure each time the door is opened or closed. It suits both large and small areas and can be placed anywhere convenient within a room and will sense all the doors feeding into the room, even if the windows are partially open.

Two jumpers are used to select various alarm sounds, from a number of tones and tunes generated by a microcontroller.

Op amp IC1 and an electret microphone detect frequencies below 3Hz, picking up air-pressure changes while ignoring normal sounds. IC1's output at pin 6 is biased at +3V by the two 10kΩ resistors at its pin 3. The sounds picked up by the electret are fed to a low-pass filter at pin 2 and the resultant output at pin 6 is a positive and negative pulse whenever a door is opened or closed.

Note that the 1µF capacitor in the low-pass filter stage should be a low-leakage tantalum, monolithic or MKT polyester type.

A PICAXE-08M2 microcontroller (IC2) senses the door trigger pulses using analog input P4 (pin 3) and once detected, the program produces an alarm sound at output P2 (pin 5). The program must check both the 'Mode' links on input P3 (pin 4) and the 'Play' links on input P1 (pin 6) using the voltage levels set by the jumpers to determine the alarm sound or music sequence to be played. The program includes an 8-second delay after the alarm operates. This prevents multiple alarms as the door is opened and closed.

An LM386 audio amplifier (IC3) is fed with the alarm signal via volume control trimpot VR1. IC3 has a gain of 20 and drives a small 8Ω loudspeaker via a 100µF capacitor. The amplifier is powered by the full 6V power supply rail before diode (D1) drops the supply to 5.4V on the remaining components. Two power supply options are shown; either a 6V battery supply or a 12VDC plugpack supply with a 7806 regulator.

You download the software into the microprocessor using the serial programming socket (ICSP) to install either the "dminder1_08m2.bas" or the "dminder2_08m2.bas" programs.

The first program has three alarm tones and three short tunes and all six are individually selected using the 'Mode' and 'Play' jumpers. The second program retains the three alarm tones but adds four kid's tunes played in rotation or four theme tunes played in rotation or all eight tunes played randomly. Once again, the 'Mode' and 'Play' jumpers are used to select the options.

Common to both programs, LKA selects 'tone' mode and LKB selects 'tune' mode, leaving LK1 and LK2 to choose the actual alarm sound or music sequence to be played. You can select either Single, Double or Triple alarm sounds or music selected from Looney Tunes, The Muppets, George of The Jungle, Adams Family, Peter Gunn, Star Wars, Batman and Indiana Jones (details in the program). Be sure to turn power switch S1 off before adjusting the jumpers.

Finally, you could customise your version by selecting other tones or tunes for the alarm sounds.

Ian Robertson,
Engadine, NSW. ($60)

The software, dminder1_08.bas and dminder2_08, available for download from the SILICON CHIP website.

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See Review April 2011

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See Review March 2010

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By NICHOLAS VINEN

Review: Rigol DS1104Z-S 4-channel DSO

This 4-channel digital scope is compact, feature-packed and offers excellent value for money. It's the latest offering from the increasingly capable line of scopes by Chinese company Rigol.

WHAT MAKES THIS scope different from others we have reviewed in the last few years is that it's a 4-channel wide-screen digital storage oscilloscope (DSO) priced under $1000. That means it's significantly more capable (and useful) than an entry-level scope for only a little more money.

Now it should be obvious to everyone that a 4-channel scope is better than a 2-channel scope but how often do you need more than two channels? In the SILICON CHIP lab, we find that this situation arises quite frequently. It allows you to, say, monitor the input and output of a circuit while using a third channel to probe points in between to see how the signal varies throughout the circuit. Or it allows you to monitor the input and the signals at three different points in a circuit. You tend to do it, just because you can and it gives a better picture of the circuit operation.

There are two DS1104Z-S models available, with 70MHz and 100MHz bandwidth. In both cases, the sampling rate is 1GS/s, dropping to 500MS/s with two channels active and 250MS/s with four.

This scope also has a number of advanced features which would have cost you an arm and a leg only a few years ago. For example, it has a 64-level intensity modulated display (like a "digital phosphor oscilloscope") which means you are much more likely to catch glitches and you get a much better idea of how the captured waveform varies from cycle to cycle – see Fig.1.

This is even more useful when you realise that it can capture up to 30,000 waveforms per second while an entry-level scope may only manage 1/10th of that. That not only means that the display intensity shows you more detail

but you also get much faster averaging.

It comes standard with 12Mpoints memory and is upgradable to 24M-points. That gives you a lot of scope to freeze, zoom and pan the display to examine the captured waveform in detail (Fig.2) – which is one of the most powerful features of a DSO, after all. It also has a very good minimum sensitivity of 1mV/div (10mV/div with a 10x probe) which is great for looking at low-level analog signals.

For a bit more money, you can also get a version with an in-built 2-channel 25MHz arbitrary signal generator. This is very handy as it doesn't take up any extra bench space and you can use the wide-screen LCD and front panel buttons to configure it.

In short, this scope raises the bar for test instruments in its price range and offers serious capabilities for hobbyists, educational users and professionals too.

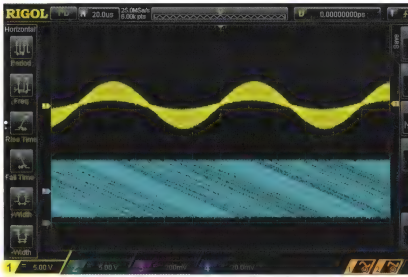


Fig.1: an amplitude modulated sinewave (yellow) showing an intensity graduated display. Below this is a frequency-modulated triangle wave. Both are from the onboard 2-channel signal generator. Note the measurement menu at left and the regular menu at right (showing storage options).

User interface

As well as having good specifications and a number of handy features, the Rigol DS1000Z-series offers an improved user interface which makes the scope significantly easier to operate than most low-cost models. For example, it has soft buttons on both sides of the screen (left & right) and since the display has a wide format, there is room for menus down both sides while still having space for a 12 x 8 division trace display in-between.

The right-side menus and soft buttons are used for the traditional purposes, ie, configuring channels, triggers, acquisition mode, mathematical transforms, utilities and so on, while the left-side menu is used primarily to set up measurements. This is one of the most common tasks required while actually examining signals, so having it easy to do is welcome.

This menu is laid out particularly well. The "menu" button at upper-left switches between vertical (voltage) and horizontal (time) measurements, while the up and down arrows at lower-left switch between the two sets of six measurement options in each case. It's then just a matter of choosing a channel and pressing one of the corresponding soft buttons to put the required measurement on-screen.

You can display up to five measurements at a time and they appear below the graticule. You will need to have good vision though (or be wearing your glasses/contacts), as the font used is tiny (see Fig.2).

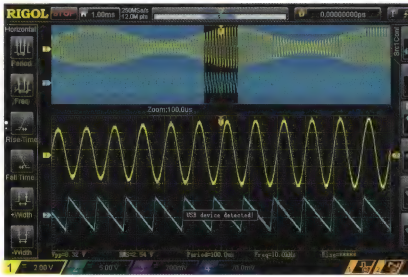


Fig.2: zoom mode with the maximum memory depth for 2-channel mode (12Mpoints). Note the length of the full capture (top). The sampling rate and memory depth used are shown at the top of the screen. Five measurements are shown along the bottom with the generator menu at right.

The measurement options don't stop there though. You can also turn on 'statistics' mode which expands this measurement display (shrinking the trace display but retaining the same number of grid squares). The same five measurements are shown but as well as displaying the current measured value, it also shows the minimum, maximum and average values.

There is also a hardware frequency counter which can be connected to any of the four inputs and appears at top-right. Plus you can bring up a display which shows 20 different measurements for a single channel simultaneously, at the top of the screen. As you would expect, this reduces the space available for traces but is handy for taking in signal properties with a 'quick glance'.

Another nice user interface feature is the fact that there is a dedicated button and three LEDs for the acquisition mode (auto/normal/single). In some cases, you will want to change this often and this avoids a lot of fiddling around with the menu system.

Serial bus support

If you are working with mixed analog/digital systems, or sometimes

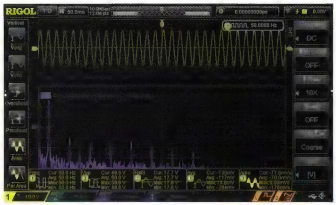


Fig.3: FFT mode, showing the harmonics of a mains waveform (via an isolating transformer). Measurement statistics mode is also enabled, showing the minimum/maximum/average values of all five measurements on the channel 1 waveform, including area under the curve.

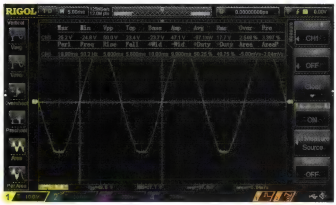


Fig.4: a closer view of the same waveform as in Fig.3 but this time with all measurements enabled. These are shown in a somewhat larger font. Any combination of the four channels can be chosen for this display; if all four are selected it takes up more than half the graticule!

work with analog and sometimes with digital, having a mixed signal oscilloscope (MSO) can be very handy. This is like a DSO but with digital inputs as well. There is no MSO option for the DS1000Z series but it can do some limited serial bus decoding using two, three or four of the analog channels.

It comes standard with a "parallel" decoding option but given that it only supports a bus up to three bits wide (ie, one channel for clock and the rest for data), it isn't very useful. However, it supports RS-232, I^2C and SPI decoding as an extra-cost option. If you have two 2-wire buses, you can decode them both. If you're only looking at a single serial bus then the remaining channel(s) can be used to monitor other signals.

The serial decoding and triggering system is very flexible. You can choose which channels map to which functions: RX/TX, CLK/DATA and CLK/MISO/MOSI/CS respectively. For SPI, if you don't want to assign an input to CS (possibly using up all your analog inputs), you can have the unit operate without it as long as there is a delay between each SPI packet.

You can also adjust the level thresholds, display format (hex, decimal, ASCII, etc), signal polarity and protocol-specific settings such as baud rate for RS-232 and address for I^2C.

The serial decoding option isn't as good as having a proper MSO because it won't leave you with many analog channels but it's certainly cheaper and should be quite adequate in many circumstances.

Signal generators

We spent some time using the optional generators for various tasks and found them quite useful. The only thing we don't really like is that the outputs (2 x BNC) are on the back but they're easy enough to access, being near the edge. They are actually quite capable generators with sine, square, triangle, pulse and DC options in addition to arbitrary waveforms.

The frequency, amplitude and phase can be set over a wide range and there's a handy on-screen keyboard (manipulated using the general purpose knob) to make entering frequencies and such easier.

The pulse mode is very useful and can be set up to give pulses over a wide range of periods, however the duty cycle is locked in the range of 10-90%.

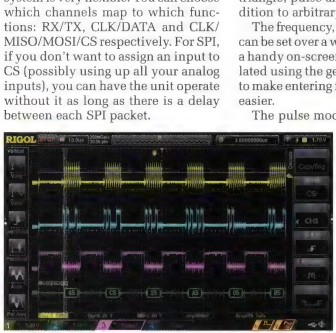


Fig.5: the optional serial bus decoding in action, with an SPI bus. The automatic cursor mode has also been enabled and is showing the clock period. The decoded values are shown in hexadecimal but there are other options such as binary, decimal and ASCII characters.

Other features

The DS1104Z has quite a comprehensive set of mathematical modes including the usual add, subtract, divide and multiply, FFT (which works quite well), integrate, differentiate, square root, log, exponential, absolute value and others. It can store and display a reference waveform too.

All knobs are also pushbuttons which perform common actions such as centring the selected channel's trace. Pressing on the large timebase knob enables a zoomed view. The memory depth can be changed to adjust the update rate/zoom window trade-off and the sampling rate can also be altered, which affects memory use.

In addition to averaging mode, it also has "high resolution" mode which we've discussed in previous reviews. This is a very useful mode which removes noise from non-repetitive waveforms and it also doesn't have the lag associated with averaging.

There is a 20MHz bandwidth limit selectable on a per-channel basis. This scope has all the trigger options you might need: AC/DC, LF/HF reject, hold-off, noise rejection. It also has a good selection of trigger modes: edge, pulse, slope, video, pattern, duration and setup/hold. There is an extra-cost option for advanced trigger modes, including: timeout, runt, window, delayed, nth edge and serial (RS-232, I^2C or SPI).

This scope also has support for manual or automatic cursors, mask (pass/fail) testing, X/Y mode, rolling

trace mode and adjustable persistence. It can save screen grabs, waveform data and configuration data to a USB drive via the front panel socket. A rear panel USB socket can be used to connect a printer and there is a dedicated print button (which can also be used to save the display to USB).

Amazingly for a relatively low-priced scope, it also comes standard with an Ethernet (LAN) socket for remote control and operation. A waveform recording and playback option is available at extra cost.

What you get

The scope itself measures 313 x 161 x 122mm and weighs 3.2kg. Four passive 150MHz switchable 10:1/1:1 probes are included along with a power cord, USB cable, quick start guide and a CD-ROM. The quick start guide is not very useful; the proper manual is on the CD as a PDF (or can be downloaded from the Rigol website).

As mentioned earlier, there are 70MHz and 100MHz bandwidth versions with and without signal generators. There are also four software options: the 24Mpoint memory upgrade, waveform recording and playback, advanced triggering options and serial decode software. These can be added on after purchase; the extra bandwidth and signal generator option can not.

Conclusion

As you can see from the above, this is a capable scope and is quite good value for money. But does that mean there's no point paying more for a higher end unit? Well, no. The DS1104Z can feel a little slow at times and that includes some noticeable delays between pressing a button and the corresponding action occurring. And you do get a bigger screen with more expensive models, including those from Rigol.

The rear panel is uncluttered and carries the two generator Source output sockets, a Trigger Out/Pass/Fail socket, a USB socket (eg, to connect a printer or to save data to a USB drive) and a LAN socket for remote control.

We would have to say though that unless you are on a really tight budget, there isn't much point buying a bargain-basement 2-channel DSO any more. The added capabilities you get with this scope compared to a real cheapie (and it isn't just the two extra channels) are well worth the difference in price.

One criticism that could be levelled at this scope is that it has a single set of knobs for the vertical settings for all channels. That means you have to switch channels with a button before making adjustments to that channel. And because those buttons are also used to turn the channels on and off, it can get a bit confusing.

Having said that, you can understand why they've done it this way – with the wide screen and all the soft buttons, there just isn't room left for four sets of knobs.

Overall though, it's clear that this is a winner in its market segment and if you don't already have a DSO, it's a good one to start with as it has so many features in a small package.

Where from, how much?

At the time of writing, Emona have the 70MHz model (DS-1074Z) for $719.40 (including GST) and the 100MHz model (DS-1104Z) for $917.40. The 2-channel signal generator (suffix -S) adds $286 to either. The other options are $160.60 (waveform recording/playback), $212.30 (advanced triggering or serial bus analysis) and $325.60 (deep memory expansion).

For enquiries or to purchase, contact Emona at testinst@emona.com.au, visit their website at www.emona.com.au or call one of the following numbers:

- New South Wales: (02) 9519 3933.
- Victoria: (03) 9889 0427.
- Queensland: (07) 3275 2183.
- South Australia & Tasmania: (08) 8363 5733.
- Western Australia: (08) 9361 4200
- New Zealand: call NSW office. SC

By NICHOLAS VINEN

Sydney Mini Maker Faire

. . . and hackerspace highlights

On Sunday 24th November 2013, Sydney's Powerhouse technology museum hosted a "Mini Maker Faire", an exhibition of various groups and businesses dedicated to people building "stuff". Well that's rather vague but it really does cover a wide range of hobbies including electronics and robotics but also 3D object fabrication, textiles, electric vehicles, sculptures, dioramas . . . just about anything you can make yourself.

THE PURPOSE OF the Mini Maker Faire was for makers to show off their completed (and in some cases, partially completed) designs and to encourage interested parties to get involved. It was a particularly good opportunity for those aged 10-18 or so (and in many cases, their parents) to learn about electronics, 3D printing and 3D construction in general and become enthused over the idea of building their own robot, gadget or other device.

The fair consisted of 60 booths spread throughout the Powerhouse Museum building. Of course, visitors were also free to experience the usual attractions at the museum including a number of locomotives, aircraft and some quite fascinating cut-away or exposed mechanisms, many of which are motorised to show how they work.

Many of the booths were staffed by organisations that our readers would be familiar with such as Freetronics (with Arduino), Bitscope, 3D Printing Systems, German RepRap (another 3D printer distributor) and even the Ripperton superbike we featured on the cover of last month's issue, shown alongside an electric scooter from Sydney Electric Vehicles.

There were also a couple of groups that you may not be familiar with but that would be of interest to SILICON CHIP readers. Primarily, we are thinking of Robots & Dinosaurs, the Sydney "Hacker Space" organisation and the Sydney Robot Workshop, who shared the same space. You couldn't miss their part of the space since it is occupied by life-size R2D2s and Daleks.

Hackerspaces

The "hackerspace" phenomenon has sprung up in the last few years to support the "maker" movement. In essence, it consists of clubs in major cities (and some large towns) around the world where members pool their money, time and equipment to set up a location where they can gather to build things, discuss building things, help each other out and generally socialise.

There are already spaces in Sydney, Melbourne, Brisbane, Adelaide, Canberra, Perth, Dubbo, Newcastle, Geelong, Townsville . . . the list goes on. A more-or-less complete listing can be found at this website: http://hackerspaces.org/wiki/Australia

So what's the benefit of joining one of these organisations and how much does it cost? Well, the main advantage is that you get a place to work on your projects. This is especially useful if, say, you live in an apartment and don't have a workshop or office where you can do your soldering, drilling, cutting and so on.

Importantly, there is also a lot of great gear that you can use or borrow while you are there, some of which you may not be able to afford or which is impractical to keep at home. At Sydney's Robots & Dinosaurs for example, there are two laser cutters, multiple 3D printers, CNC mills, lathes, band saws, drill presses, power supplies, oscilloscopes, soldering stations and a large variety of hand tools and assorted components that members can use.

There is also quite a variety of raw materials that members can purchase, such as sheets of acrylic, plywood, plastic and metal rods, reels of 3D printer plastic and so on. The cost of these "consumable" materials is charged on top of the membership fee. Generally, hackerspaces also provides some basic refreshments such as bottled water, at a nominal cost.

The typical cost to spend a day (or part of one) at an Australian hackerspace is generally $10-15 plus the cost of any supplied material you use. If you attend more than once a week, it's cheaper to pay the monthly membership fee which is around $40-60. Not surprisingly, the weekend is the most popular time to be there but the space is open on some weekdays too, mostly in the evening.

But perhaps just as important as the access to all this equipment is the fact that the members and operators of the club have the knowledge and experience to operate it all (and do so safely) and are more than happy to help beginners learn how to do so successfully. For example, they can show you how to draw up a design in a CAD package and then cut and/or engrave it out of plastic or wood on the CNC laser cutter.

At the time of writing, Robots & Dinosaurs is in the process of moving from Gladesville to Meadowbank.

Activities involved

Different hackerspaces will emphasise different skills and hobbies depending on the make-up of the membership. There is certainly a fair amount of electronic tinkering going on at Robots & Dinosaurs, perhaps not surprisingly mainly in aid of building robots or remote-controlled vehicles of various descriptions. A number of members work with Arduinos or similar devices, controlling stepper motors, servos, lights, producing sounds and so on.

Having said that, there is also a lot of time spent designing and building 3D mechanical objects with no electronics at all (or maybe just something basic like a motor). For example, a motorised wooden wheel was demonstrated by the R&D crew at the fair. It picks up marbles from a tray at the bottom and lifts them up to the top, where they roll down a ramp and the cycle repeats indefinitely.

We guess is that you could call that a "kinetic sculpture". Many members also like to make static 3D objects from laser-cut patterns with various intriguing shapes and forms. In fact, the laser cutter is one of the most popular tools at the space; so much so that they recently built a larger and more powerful one which includes an impressive CO_2 laser tube, over 1m long, for cutting faster and through thicker material (up to about 12mm).

While SILICON CHIP readers will most likely be interested in attending a hackerspace in order to work on electronic projects and brainstorm designs with other knowledgeable members, it is quite fascinating to see the other types of projects that members work on, many of which are quite ingenious.

See it for yourself

Since it was a success, attracting more than the expected number of visitors (3000), it's likely that another Mini Maker Faire will be held in Sydney during 2014.

Similar fairs were held last year in Melbourne (Eurisko, November 2-3 at the Arts House Meat Market) and Adelaide (April 6, Adelaide College of the Arts), so look out for repeat events this year. SC

Completing the "TINY TIM" Stereo Amplifier

Part 3 – By Nicholas Vinen

In this final instalment we finish building the Tiny Tim amplifier by fitting all the modules into the case and wiring it up. We'll also look at testing the unit, its final performance and some other useful tidbits.

At this stage, you will have finished building the main amplifier PCB and power supply and you should also have prepared the case, including drilling holes in the base for mounting the modules.

But before we screw them in, it's easiest to do some of the wiring first.

Start with the wiring between the two chassis-mount RCA sockets, the slide switch, the RCA plugs for the DAC and the leads to connect to the amplifier PCB. This wiring is shown in the upper-left corner of Fig.6 on page 82 of the December 2013 issue.

Strip and tin the wires to go to the PCB but leave these loose; the rest of the wiring can be completed in-place.

Note that depending on how close you have mounted the RCA sockets to the slide switch, it may be impractical to use shielded cable for these connections, in which case you will have to use ordinary hook-up wire instead. In this case, keep the wires as short as possible and run the two signal wires close to the ground wire(s) to minimise hum pick-up.

Fitting the DAC

With that done you can then mount the DAC board. As explained last month, to save space we fitted ours directly above the RCA sockets and slide switch and we used a combination of various Nylon tapped spacers, nuts and screws to support it.

Essentially, what you need to do is fit the DAC connectors and switch through the rear panel holes you made earlier and measure how high it sits above the bottom of the case, then pick the next shortest tapped M3 spacers you can get.

Experiment with how many M3 nuts or washers you need to fit to the screws before attaching the spacers so that the DAC board naturally rests on these spacers when it is in place.

It's then just a matter of using a few more Nylon M3 screws to hold it in place on the top. The holes on the DAC board are a bit bigger than usual for M3 screws but the screw heads should be sufficiently large to hold it down. Otherwise, use Nylon washers under the screw heads. You can then plug the two RCA cables you soldered earlier into the DAC outputs.

Output & pot wiring

The next step is to fit the front panel components and connect wires in preparation for the final assembly. This wiring consists of the following runs; again, refer to Fig.6 in the December 2013 article:

1) Two red wires from the left and right channel pins on the headphone socket, long enough to reach the amplifier board, plus a black ground wire of a similar length.

2) Two long red wires from the switched left and right channels pins on the headphone socket to run along the bottom of the case and back to the two red binding posts. Remember to slip a couple of pieces of heatshrink tubing over each wire before soldering them to the binding posts and it's also a good idea to wrap the exposed copper strands securely around the binding post pin before soldering it (which will require a hot iron).

That done, slide the heatshrink over the solder joint and shrink it down, then repeat for a double insulating layer (see photos). We attached several adhesive plastic wire clips to the bottom of the case to hold these wires in place, roughly along the paths shown in Fig.6.

3) Two black wires from the black binding posts, long enough to reach the rear of the amplifier board and connect to the ground plane. These should also have two layers of heatshrink insulation over the solder joints.

4) Two stereo shielded wires soldered to the volume control pot, long enough to reach to the pot connections on the amplifier board. Wire these as per Fig.6 last month.

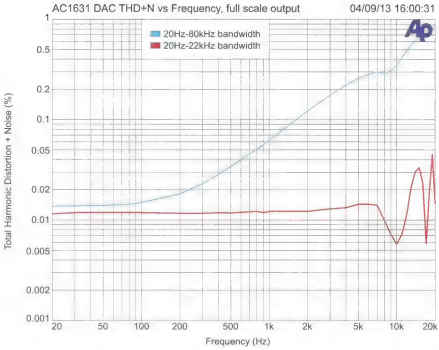
Mounting modules & testing

First, fit the power supply module in place by screwing its four tapped spacers into the bottom of the case. Use three short steel M3 machine screws and a Nylon M3 machine screw for the right-rear corner, ie, the mounting posts which already has a Nylon screw in the top.

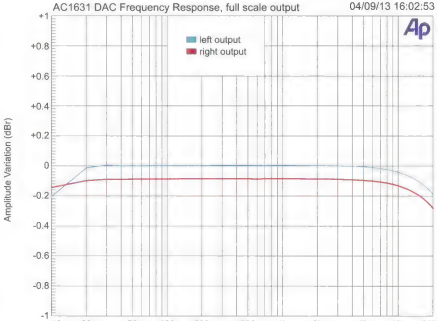
Cut a 60 x 40mm piece of fibre insulation (eg, Presspahn) and then score and fold it 45mm from one end. Drill two holes in this to correspond to the two holes in the bottom of the case, near, the power supply board and attach it using M3 Nylon machine screws and nuts, as shown in the photos. This prevents any wires which may come loose from contacting any of the mains-potential components on the PCB.

Connect the mains cable to the left-most pin header terminal and feed it through its grommet at the rear of the case (ie, the one that it went through originally).

At this point, with the power supply in the case, it's probably a good idea to check that it is working properly so plug the switch in and check that it is properly isolated. To do this, set your



Distortion vs frequency at full scale output for the AC1631 DAC module. It's an oversampling type DAC, rather than delta-sigma, hence the rather steep rise in distortion with increasing frequency. But when the output is filtered with the 20Hz-22kHz bandpass filter (red trace, simulating human ear response), most of the distortion harmonics are eliminated. Comparing this graph to the others shows that when using a digital input, the DAC is generally the limiting factor in performance.



The frequency response of the AC1631 DAC is pretty flat, being down by only 0.2dB at the high end (20kHz) and virtually flat to 20Hz at the low end. Note that it does not handle Dolby Digital, DTS or other compressed audio streams so if connected to a TV set or disc player, the unit should be configured to output a linear PCM stereo digital signal. Most disc players and many TV sets offer a "down-mixing" option, specifically to allow the digital audio output to be connected to devices like this.

Reproduced from last month, this photo shows the placement and interconnection of the PCBs within the Tiny Tim amplifier.

DMM to high ohms range (ie, megohms) and connect one probe to the mains plug Active pin and one to an exposed piece of metal on the chassis. Check that there is no connection (it should read "oL" or similar).

Repeat the same test with the Neutral pin. Then check, with the power switch on, that there is no connection from the mains Active pin to any of the three terminal block outputs on the power supply PCB. This verifies that the transformer insulation is intact. Assuming that's all OK, switch the DMM to DC voltage measurement mode and check that the power supply fuse cover and adjacent Presspahn shield are in place, plug in the mains cord and turn it on.

Without touching the mains section of the power supply board, measure between the middle pin of the terminal block and either side. You should get readings of approximately ±20V (likely a bit higher). Switch off and check that these drop to near 0V within about 30 seconds. This confirms that the power supply board is working and you can then switch off and unplug the mains and then the mains switch from the power supply board.

Note that with some terminal blocks, there may not be a good connection to the screw on top when there is no wire inserted so it's best to probe the wire openings if possible.

Amplifier module installation

Before fitting the amplifier module to the case, make sure you have soldered the three power supply wires as shown in Fig.6 last month and that they are long enough to reach the power supply output terminals when it is in the case. A 2-wire cable should also be attached for the 12V DC output as described last month. If you fitted sockets to the amplifier board, plug in the ICs now but make sure their pin 1 dot lines up with the notch on the socket.

You can now mount the amplifier module using four tapped spacers and eight short M3 machine screws. The MiniReg board is mounted in a similar manner (note that no heatsinking or regulator tab connection is required) and the two-pin header you wired to the amplifier board's 12V rail earlier can now be plugged into the MiniReg's input. Check the polarity, ie, ensure the grounds of the two boards are continuous, eg, from the OUTPUT - pin of CON4 on the Minireg to the tinplate shield on the amplifier board.

You can also plug in the power LED into the MiniReg now. But we don't want to connect the power supply directly to the amplifier PCB just yet, with the exception of the 0V (black) wire which can go to the central output on the power supply board. Leave the other two (red and blue) loose for now.

Now solder the remaining wires to the PC pins on the amplifier board, specifically the six from the pot, three from the headphone socket, four for the inputs (from the chassis-mount slide switch) and two from the black binding posts.

It's a good idea to slip a short length

of heatshrink tubing over each wire before soldering (slide it far along enough the wire that it doesn't shrink from the heat) and then shrink it down over the solder joint when it's cooled to provide some strain relief.

More testing

We now want to check whether the amplifier module is working and the best way to do this is to temporarily connect a couple of 100Ω 5W safety resistors in series with the supply leads so that if something is wrong, you will have time to switch power off before any damage occurs. This also reduces the chance of a problem when adjusting the amplifier's quiescent current.

If you have enough room, you can insert one lead of each safety resistor into one of the terminal block outputs on the power supply board, screw it down and bend it up so that the resistors stick up vertically. It's then just a matter of running a clip lead from the other end of each resistor to the appropriate power supply wire for the amplifier module.

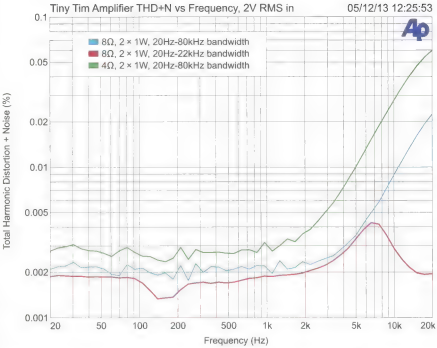
Make sure that the clip lead from the red wire goes to the safety resistor at the positive output terminal on the power supply, which is furthest from the corner of the board. If necessary, use clip leads at both ends of the safety resistors and they can sit outside the case. But regardless, make sure that the exposed metal of the alligator clips can not make contact with anything else – a good way to ensure this is to temporarily wrap them in electrical tape.

For now, do not connect the DC output from the MiniReg board to the DAC's power supply input socket. Re-connect the mains power switch, do a final check to make sure there are no stray wires that could short to anything (especially near the power supply board!) and turn trimpots VR2 and VR3 on the amplifier board fully anti-clockwise.

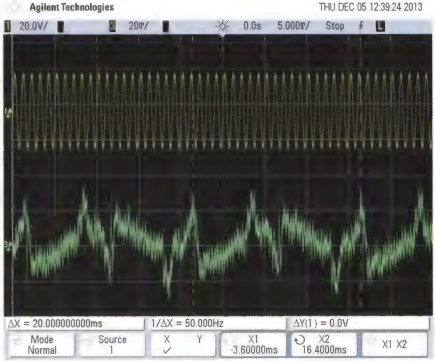
You can now plug the unit back into mains, switch it on and check the voltage across each safety resistor using a DMM set to DC volts mode.

Don't go near the mains side of the power supply. You should get a reading below 10V in each case (typically around 8-9V); if not switch off immediately and check for faults in the wiring.

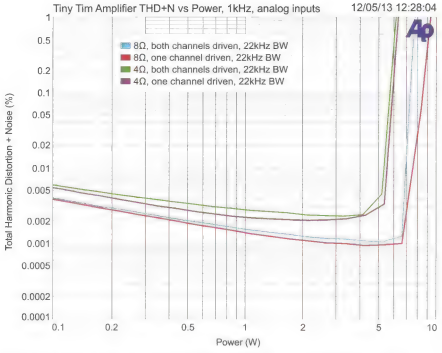
If the wiring looks OK but the voltages are too high, there is likely a problem with the component installa-



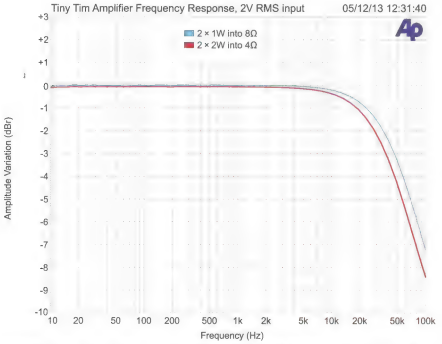
Distortion versus frequency from the completed amplifier under a variety of conditions. This is somewhat higher than what was shown for the amplifier module/power supply combination in the October 2013 issue. This is almost entirely due to increased hum and rectifier buzz pick-up now that the boards are mounted close together in the case. If we measure the distortion with a 400Hz high-pass filter to eliminate mains 50Hz hum and its immediate harmonics, the readings drop substantially, to around 0.0006%.



The distortion residual of the amplifier output at 1W with both channels driven into an 8Ω load (green) compared to the output itself (yellow). As you can see, it is mainly a combination of 50Hz, 100Hz and even order harmonics of these frequencies, indicating that it's due to hum pick-up from the power supply. The actual distortion products at 2kHz and above can be seen superimposed on this waveform at a much lower level.



Distortion versus power for a 1kHz signal under various conditions. As is typical, distortion is lower into 8Ω loads than 4Ω due to the lower output current for the same power level. Continuous power output is below 10W but music power (ie, the power available for short bursts) is higher than this, at about 10W for both 4Ω and 8Ω speakers with both channels driven. Note that despite the level of hum measured, even with the volume turned up and our ear very close to the speaker we could barely make it out (inputs must be terminated for this test).



Frequency response of the complete amplifier. Note that this shows a much greater roll-off at the high end (down by about 1dB at 20kHz) compared to the graph published in the October 2013 issue. That's because since taking the earlier measurements, we decided to increase the input filter capacitors to 4.7nF to give better attenuation for the harmonics in the DAC output. You could lower this value slightly to give a slightly flatter high-frequency response but then it would be less effective at attenuating DAC switching noise.

tion or the modifications to the amplifier board. Assuming the voltages are OK, measure the voltage between each pair of red/black binding posts (ie, the output offset voltage). It should be below 20mV. If it's much higher than that, there is a fault so switch off and check your work carefully.

Otherwise, now is also a good time to check the output of the MiniReg board, either at CON4 or if you have plugged it in, the DC plug (with the red probe inserted through the end and the black in contact with the outside of the barrel).

Turn its adjustment trimpot and check that the output voltage varies. You can then set it to 6V±0.1V.

Next, connect the DMM between TP1 and TP2 on the amplifier board and slowly rotate VR2 clockwise. The voltage should start out low (just a few millivolts) and rise as you turn the pot. Stop once it reaches 15mV.

Note that we indicated a reading of 30mV in the circuit diagram on page 61 of the October 2013 issue but have found that the heatsinks run a bit hot at idle; 20mV is plenty of bias in practice. We're setting it to 15mV now because it will increase a bit once the safety resistors have been removed. Repeat this procedure for TP3/TP4 and trimpot VR3.

Check the voltage across the safety resistors again. It should have increased to around 12V and they will be getting a little warm.

Having passed those tests, the amplifier board is likely working but if you want to be really sure, you can do a live signal test by connecting a pair of speakers and some sort of signal source. But if you do this with the lid open, you need to be careful not to go anywhere near the power supply. In fact we would switch off and unplug the unit while connecting the speakers and signal source.

Of course with this sort of test it's always a good idea to turn the volume control right down before switching back on and advance it slowly. While the power switch is off you should also check that the input selector slide switch is in the appropriate position for the analog inputs.

With the safety resistors in place, only a small amount of power will be available but you should be able to get clean audio at a reasonable volume.

You can then switch off, unplug the mains cord and wire the amplifier

module directly to the power supply, making sure you hook up the wires to the same terminals as you used earlier. You can now also connect the output of the MiniReg to the DAC board.

That should complete the wiring. To keep it neat and safe, tie all the cables into bundles or to adjacent posts so that they can't move and break loose should the unit be subject to vibration or shock.

If in doubt, refer to our photos (including those published last month) to see how we did it. Your completed unit should look much like ours although obviously it will vary somewhat depending on which case you used.

Now is a good time to repeat the live signal test but this time without the safety resistors, you should have the full power output of up to 10W per channel available. Once it's warmed up a little bit, re-adjust VR2 and VR3 to get 20mV across the associated test posts.

Assuming it all works and sounds good, you can switch off, unplug the mains cord and attach the lid, volume knob and any other ancillaries to complete the unit such as feet. Make sure the mains cord is properly anchored using the original method once the lid is in place; in some cases the lid helps to hold the cordgrip grommet in place.

The accompanying graphs show the performance of the completed unit and the integrated DAC. These measurements include power supply noise, hum, RF pick-up in the wiring and so on so they aren't quite as good as the performance of the amplifier module itself but still pretty good and we think you will find the sound quality is "up to scratch".

Depending on what speakers you are using, you may want to consider adding a Bass Extender (described elsewhere in this issue) to your new hifi setup. SC

Modifying the DAC for more output

The pre-built DAC board we have used in this project (Jaycar AC1631) has an output of around 1V RMS while most CD/DVD/Blu-Ray players and high-end DACs have an output closer to 2V RMS. This is generally not a big problem but it does mean that if you are switching between the analog and digital inputs, you will need to adjust the volume control each time.

Reader Gavin Krautz wrote to us to explain that he has this DAC and grew tired of constantly changing volume levels when switching inputs; he came up with a simple way to increase the DAC output level to around 2V RMS. As he explains:

The DAC contains a BH3544 headphone amplifier to drive the outputs, which has a default gain of 6dB. However, its gain can be reduced by inserting resistors in series with the signal going to pins 3 and 5 of the IC. In the Jaycar DAC, these resistors (R25 and R27) are 90kΩ, which sets it gain to 0dB (ie, unity). The formula given for the gain is 6dB + 20.log10(90kΩ÷(90kΩ + R_{ip})).

This means you can increase the output gain by up to 6dB by changing these resistors. I initially considered making the output gain switchable, or shunting R25 and R27 to increase the gain, but in the end I simply shorted them out to restore the 6dB default and I have been very happy with the result.

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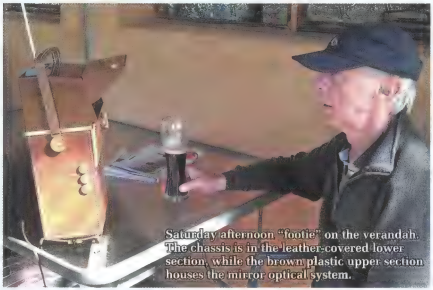
By Ian Batty

Philco Safari: the first transistor portable projection TV set



Saturday afternoon "footie" on the verandah. The chassis is in the leather-covered lower section, while the brown plastic upper section houses the mirror optical system.

Released in June 1959 and costing $250.00, the Philco "Safari" was the world's first battery-powered transistor portable TV set. It was an unusual design employing a simple projection system to enlarge the image produced by a tiny 5cm upwards-facing picture tube buried inside the case.

PUBLIC TV transmissions essentially began in 1936 with BBC and German broadcasts but it wasn't until after World War II that television really began to take off. Indeed, the 1950s saw the introduction of what could be called the "Television Age".

The all-valve sets of that era, with their progressively larger and larger picture tubes, were power-hungry monsters. Small radio sets on the other hand had been around for some time, with an explosion of personal portables and so-called "shirt-pocket" sets in the late 1940s. Miniature and later subminiature valve designs were then rapidly replaced by all-transistor sets. Regency and Sony set the pace, followed rapidly by other major electronics companies.

The start of Philco

The Philadelphia Storage Battery Company, registered in 1906, began releasing products under the Philco brand in 1919.

Philco had been early adopters of transistor technology, releasing their proprietary Surface Barrier Transistors (SBTs) in 1953 and their first transistor portable radio (the T7) in 1956. Philco also developed what is claimed to be the world's first general-purpose, solid-state computer, the S-2000, in 1957.

With such a pedigree, it's no surprise that Philco joined the race to develop an all-transistor TV set. They already had a fine catalog of valve sets and were active in developing and manufacturing cathode ray tubes (CRTs). They would go on to develop the "Apple" single-gun colour CRT.

Philco had even employed television pioneer Philo Farnsworth for awhile. As in the race between Regency and Sony for the first transistor portable radio, Sony were breathing down Philco's neck to be first to market with a portable transistor TV set. Philco eventually won the race with their Safari model but Sony came a creditable second with a more usable, better-designed set designated the TV8-301.

It's always easy to be critical of "the first" of anything. There's a story that some critics once ridiculed Christopher Columbus for discovering America, claiming it was no great feat. He simply challenged them to take a fresh egg and stand it on end. They failed, of course, so Columbus took the egg and very delicately tapped it on the table, crushing the end in just enough to make it stand freely. "That's no great trick," they said.

"Perhaps not. But I did it!"

Philco Safari: first look

The set featured here is the second such unit to come into my possession. The first was fine electrically but its parabolic mirror (used to reflect and enlarge the image from a small upwards facing CRT) had lost its reflective surface and the picture was only barely viewable.

By contrast, this second set worked

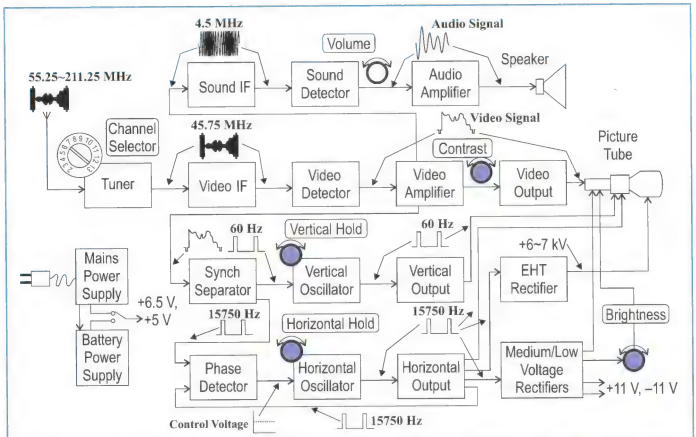


Fig.1: the major blocks in the Philco Safari portable TV set. It's pretty much a standard design for a monochrome TV set. Note that the deflection waveforms have been simplified and may not exactly match those in a working unit. Note also that the IF and deflection frequencies shown are for the American NTSC system.

first time. It easily tuned in my bench-top RF converter set-up, thereby allowing me to view analog versions of local digital television transmissions. We'll look at the signal conversion set-up later in the article, along with a method for dealing with the NTSC (US) sound channel IF which is at 4.5MHz, rather than the 5.5MHz used here in Australia.

As an aside, the Philco Safari was featured in cover articles in several magazines, among them "Popular Science" of August 1959 and "Electronics Illustrated" of November 1959.

Circuit description

The main chassis diagram covers three pages and there's another for the tuner. However, we'll simply look at the main features of the set instead of describing the circuit stage-by-stage. Before going further though, note that the Philco Safari is an NTSC set and so has vertical and horizontal frequencies of 60Hz and 15.75kHz respectively.

Fig.1 shows the block diagram. The Safari uses 21 transistors (all PNP types), 12 semiconductor diodes, two high-voltage rectifiers and a picture tube. The main power supply (described in detail later) is positive to ground but a subsidiary negative-to-ground power supply is also derived from the horizontal output stage.

The tuner uses a simple multi-wafer ganged switch with coils wired between its contacts. This has the advantages of simplicity and low cost compared to a turret tuner but these advantages are offset due to the fact that any adjustments interact between switch positions.

In operation, the channel selector "clicks" between channels, much as a turret tuner would do.

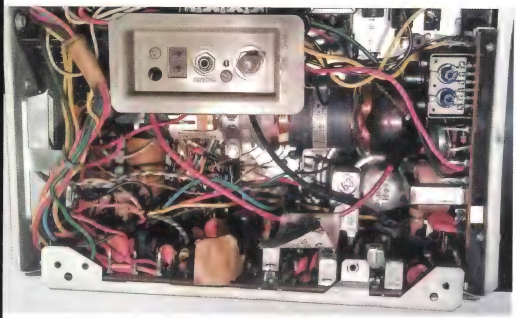
Philco transistor packages

This is a VHF-only set – UHF transistors were not available at the time of production. It uses an RF amplifier, converter and a separate local oscillator.

The wide bandwidth demanded by TV signals (some 6MHz for NTSC), combined with the high IF (intermediate frequency) of 45.75MHz results in low IF stage gains. As a result, there are four stages in the main video IF strip. In addition, feedback capacitance is significant at 45MHz, so each stage has a neutralising circuit. Two tuned "traps" help control the IF passband and "notch" the 41.25MHz sound converter signal, thus preventing possible visible interference in the picture.

Most of the transistors used in the Safari are proprietary Philco types so suitable substitutes would have to be found if they require replacement.

The video section begins with a conventional diode demodulator, in turn feeding an emitter-follower first video amplifier. The contrast control feeds



This view inside the Philco Safari TV set shows the chassis construction. The deflection board is at the top of this picture, while the IF/audio board is at the bottom. The picture tube (or CRT) is located in the centre.

a variable video signal to the video output stage which delivers around 7.5 V peak-to-peak (p-p) to the picture tube. This stage uses dual supply rails of around ±11V or 22V total.

The sound channel begins with a "pick-off" at 4.5MHz from the first video amplifier stage. This feeds two sound IF stages (amplifier and limiter) to provide a fairly constant signal to the demodulator, thereby eliminating any amplitude modulation (AM) components and interference.

Like the video IF stage, the sound IF stage uses neutralisation. The FM demodulator uses a Foster-Seeley discriminator rather than the more common ratio detector.

Audio from the demodulator (detector) is fed via the volume control to a conventional audio driver stage, the output of which is then transformer-coupled to a push-pull output stage. This audio section is very similar to that found in portable transistor radios.

Chassis details

Inside the unit, the various circuit board assemblies and other components are mounted on a plated steel frame. Note that the battery carrier has been removed from the unit shown in the photo.

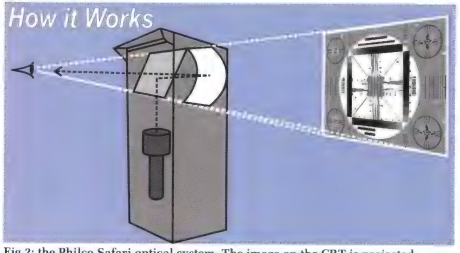


Fig.2: the Philco Safari optical system. The image on the CRT is projected upwards to an angled, half-silvered mirror. From there, the image is reflected and magnified by parabolic mirror. The final enlarged image, as seen by the viewer, appears to be about 1.2 metres behind the set.

The vertical amplifier delivers a broad voltage pulse to the deflection coil, relying on the coil's inductance to produce a linear current and thus a linear sweep over the picture tube's screen. Horizontal deflection also begins with a transformer-coupled oscillator. Since the horizontal sync signal is extracted directly from the video signal, the sync separator has little damping effect on noise impulses.

To compensate for this, the horizontal sync circuit uses a dual-diode phase comparator. This detects any difference between the incoming sync signal frequency and the frequency of the horizontal oscillator and generates an error voltage. This error voltage is then applied to the oscillator, forcing it to synchronise with the received sync pulses.

Filtering of the phase detector's output greatly reduces the effect of noise impulses on the oscillator's stability (this circuit is now commonly known as a phase-locked loop or PLL).

As with the vertical output stage, the horizontal output stage delivers pulses to the deflection coil via the output transformer. In this case, however, a damper diode also helps ensure a linear current sweep across the screen.

There is a short period during each sweep where current in the deflection coil falls (or collapses) to zero. This creates a short, high-voltage pulse somewhat like the spark pulse in a car ignition coil. The resulting pulse train is then fed to a transformer to provide four output voltages.

The picture tube receives some 6-7kV via a vacuum-tube voltage doubler/EHT rectifier connected to the output transformer's high-voltage secondary. In addition, lower-voltage taps drive half-wave rectifiers that provide +280V for the picture tube electrodes, +11V for the IF amplifier strip, video amplifier and vertical oscillator, and -11V for the video amplifier.

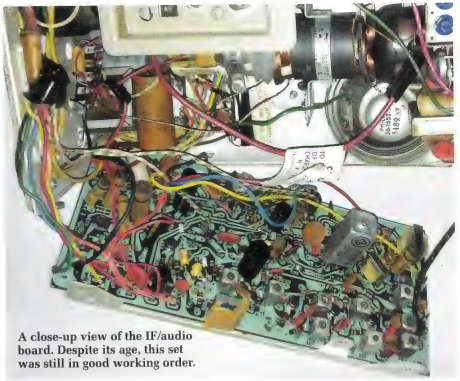
The picture tube (or CRT) is Philco's own two-inch (5cm) magnetically-deflected 2EP4, the "P4" denoting a white phosphor. Unlike the 2EP4, picture tubes this small are commonly electrostatically-deflected "CRO" types. However, electrostatic deflection demands many thousands of volts in basic tubes – voltages not possible with the transistors of the day.

By contrast, magnetic deflection currents can be easily handled by transistors powered from low-voltage

supplies and transformer-coupling between the output stage and the deflection coils. As well, the small screen size means a smaller deflection angle than the common 70°+ of conventional tubes. This simplifies circuit design and reduces power consumption.

Magnetically-deflected tubes generally use high accelerating voltages (with the advantage of potentially higher brightness) and the 2EP4's final anode voltage is some 6-7kV. The 2EP4's circular face projects upwards through a rectangular mask to a partially-silvered mirror angled at 45°. A portion of the resulting image is then reflected backwards to a concave mirror.

This mirror produces a magnified virtual image with an apparent diagonal of about 35cm (or 14 inches). Unfortunately, the combination of partial reflection and magnification reduces image brightness considerably.



A close-up view of the IF/audio board. Despite its age, this set was still in good working order.

Power supply

The power supply uses a 110VAC mains transformer which feeds 7.5VAC to a full-wave rectifier. After filtering, the set receives supply rails of -6.5V and -5V for all stages not fed by the horizontal output stage. The set can also run on a 7.5V battery pack, rechargeable from the mains supply.

Since many stages derive power from the horizontal output transformer, this set will appear dead unless the entire horizontal deflection system is working. This is common with transistorised TV sets. Because of this, a "dead" transistor TV set may have a perfectly good mains supply, so be sure to check the horizontal output stage if the main supply voltages are normal but one or more stages are "dead".

Compromises

The Safari uses "simple" AGC that responds to the strength of the IF signal and thus to the average picture level (APL). The problem is that, with negative modulation, dark pictures give higher APLs, forcing the AGC to reduce the gain and make the picture appear even darker. The opposite happens with bright pictures – in this case, the low APL allows the AGC to relax, thereby increasing the gain and making the picture over-bright.

Additionally, the video circuits are AC-coupled, so the original DC value for picture black is lost. As a result, the bias level on the picture tube "floats" at the average level of the signal. This means that dark pictures will become artificially bright as the average level drifts.

Basically, a more advanced design would give constant black levels so that a very dark object remains very dark, whether appearing in a brightly-lit scene or a dark one.

Condition

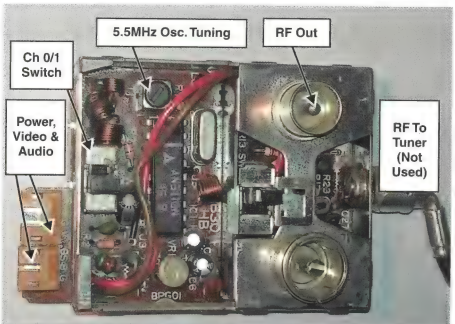
Despite its age, this set worked just fine as it came to me. Most of the transistors used are proprietary Philco types but it's unclear whether they are SBTs or alloy-junction transistors. Detailed specifications for the Philco "T1nnn" types were unavailable but Ernst Erb's Radio Museum gives basic descriptions.

As an example, transistors such as the AF186, with its 860MHz cut-off frequency, could replace the tuner's RF amplifier (T1561). However, it's the high-power components that are more likely to fail and the vertical output transistor (T1601) could be replaced by an AD149 which has a similar package and is described as "suitable for vertical output service".

The internal battery had died long ago and left a "corrosion hole" in the case due to leakage. It's about the right size for a C-cell repack to restore it to true portable operation.

TV sets invariably use many specialised parts, particularly in the timebase circuits. Such parts may be unique to one model and these can be a real problem (if not impossible) to obtain

An off-air picture on the Safari, as seen by the viewer. The image has an apparent diagonal of about 35cm.



This RF converter was salvaged from an old National Panasonic VCR. Retuning the 5.5MHz oscillator to 4.5MHz will give an audio IF output that's compatible with US NTSC sets such as the Philco Safari.

as spares, particularly in vintage sets such as this. Although it's possible to get transformers rewound, the wise collector will begin with a working set rather than attempting to repair a "renovator's delight".

Television IF alignment is also a laborious business, as I can confirm. Don't expect that "a bit of a fiddle" will improve picture quality. In fact, any temptation to fiddle with IF alignment should be resisted unless absolutely necessary. IF alignments don't change much over time and I would only get out the sweep generator if I'd done significant work on the IF strip.

Using it

The Philco Safari is a very tall set and looks like it is in constant danger of tipping over. In practice though, it's quite stable due to a stand that allows it to be positioned upright for convenient viewing.

As mentioned, the optical system means that the reflected image isn't as bright as the smaller, original image on the picture tube. However, picture clarity is aided by a flip-up hood that shades the top and sides of the viewing area. In addition, the CRT's face is "hidden" within the case, so objects in front of the set create fewer reflections to interfere with the viewed image.

More importantly, the CRT's faceplate is shielded from ambient light, so the brightness can be set to a reasonable level for comfortable viewing. That said, the Safari does benefit from careful placement when used outdoors.

How good is it?

The "Popular Science" report rated the Safari's picture as "excellent: crisp, detailed, natural in tone". In addition, the sound quality was "average for TV" and the sensitivity was "remarkably good for such a compact receiver".

Of course, they were judging it by the standards of the day but what did I think? In short, the picture clarity is good. The simplest test for any analog set is to tune to a blank channel and observe how fine the "snow" (set noise) is. Basically, fine snow means good picture clarity. The brightness was, as "Popular Science" stated, adequate for daylight viewing.

New life for old tellies

There would still be some of these old sets "out there" but with analog transmissions ceasing, the only place I can use the old Philco is in my workshop or display area.

It's great to have this set in working order, though. There is only one "first" of any generation of technology. Also, the first set I acquired still needs repair, so I'm on the lookout for a non-working set that may be able to donate parts. Furthermore, I expect that my local Astronomical Society will know about mirrors and be able to help out with resurfacing.

RF converter

A recent "Radio Waves" article, by Graham Dennes (April 2013), details an off-the-shelf RF converter that will allow you to fire up any old analog set, whether valve or solid-state. Be aware though that many cheap converters only tune over the UHF band and do not suit older VHF-only sets.

As an alternative, you can "liberate" the RF converter from a junked VCR. The signal output is usually switchable between channel 0 or 1/2. Again, some of these VCR converters are UHF only and are not suitable for use with older VHF-only sets.

If you can salvage a converter, it's easy to house it in a box and power it from a suitable DC supply (usually 6-9V). You then feed the video/audio outputs from a digital receiver or set-top box into the converter, connect the converter's output to your old analog TV and you're in business.

If necessary, you can open up the converter and tweak the oscillator that generates the 5.5MHz FM IF for the Australian television standard. They mostly use a simple slug-tuned oscillator and tuning down to 4.5MHz will give an audio output that's compatible with US NTSC sets.

Similarly, retuning a "video beamer" (a high-powered converter with a radiating antenna) allowed me to send a good signal well across the workshop.

Variants

The Philco Safari comes in two models and four variants. The Model H2010L came with a brown leather case, while the model H2010BL has a black leather case. In addition, each model has an early (1959) version and a later (1960) version. The latter eliminated the sound take-off transformer and there were some changes to the transistor types used!

Further reading

You can find the "Popular Science" review of the Philco Safari on Google Books – just search for "popular science august 1959", click on the August 1959 cover and go to page 64.

Technical information (for members only) is also available from Ernst Erb's Radio Museum www.radiomuseum.org SC

ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Speed regulator for wood lathe

I was given an old 4-speed belt-driven wood-turning lathe. It has a lot of things missing and items that need fixing. I checked my old SILICON CHIP magazines for an electronic speed regulator and could not find what I was looking for.

My question is, and I provide the motor specification, is there a project in existence and published to build a speed regulator? If so, could you please assist me to make up my mind if it is worthwhile to make a speed regulator or spend monies on a new lathe?

The specification of the motor is as follows: Class E, single phase 1/2 HP 50Hz, 1440RPM, 240VAC, 3.3A. (B. V., via email).

● Your lathe is powered by an induction motor and for that you need our Induction Motor Speed Controller which was described in the April & May 2012 issues (with revisions in the August & December 2012 issues). You can purchase the updated online articles on our website or you can order the relevant back issues.

Having said that, since your lathe has four speeds via the pulleys on the belt-drive, we wonder whether you really need a speed controller, given that the lathe will only be used for wood turning.

Smart Fuel Mixture Display

I have a question regarding Smart Fuel Mixture Display (SILICON CHIP, March 2004). I am using the kit on a turbo car which is fitted with an Holley Pro-Jection Throttle Body injector – which does not have a Mass Air Flow sensor. Can the Lean Out Alarm function of this kit be used with a source other than a Mass Air Flow sensor, for example Throttle Position? The Holly Pro-Jection does have a TPS. (G. B., via email).

● The TPS signal can be used instead of the MAF sensor output provided the voltage goes higher with increasing throttle openings.

Fish caller wanted

In the early sixties, I purchased an American magazine which featured a fish caller project for those who fished for a recreational activity so, I was wondering could SILICON CHIP do something similar? The device emitted a sound which attracted fish. (D. S., via email).

● We have considerable doubts as whether such devices really work but we will investigate. It is interesting to note that you can now purchase a "Fish Caller" App for a smart phone. Now that is really stretching credibility. The amount of sound which could be transmitted from a mobile phone, to be heard by fish, must be close to zero.

Ignition coil for Jacob's Ladder

I wish to build the Jacob's Ladder project from the February 2013 issue. I live in England and while I can quite understand the rationale behind using

Changing The Switching Frequency Of A Speed Controller

I purchased a "High Current Motor Speed Control for 12V & 24V Systems" from Jaycar. The purpose of the purchase was to control the speed of a fan motor installed in the roof of my motor home. The speed controller functions perfectly, however there is an irritating "squeal" from the motor which I understand is a common problem with PWM circuits controlling DC motors.

One suggestion is that I increase the frequency of the oscillator by 10 times from the current 2kHz to 20kHz, to place the "squeal" outside of the audible range. Do you agree with this suggestion, and in addition, what RC values would you suggest? The fan motor is a 12V DC unit pulling about 4.7A running off a battery or a switchmode power supply, depending on selection of power to the motor-home (L. C., via email).

● We are not sure which controller you have. There was the June 1997 12V motor speed controller, the March and April 2008 40A controller and the June 2011 version. The June 1997 and June 2011 versions would be more suited for the 4.7A current draw. The motor speed controller from March/April 2008, although suitable, is unnecessarily over-rated for the small fan.

All of these controllers can be changed in operating frequency with the 2008 and 2011 versions having adjustments. The frequency should be set for the minimum noise from the fan motor.

The 1997 unit can be altered to give a 10x higher frequency by changing the capacitor at pin 5 of IC1 (TL494) from 68nF to 6.8nF.

Similarly, for the 2011 version, the overall frequency range can be altered by changing the capacitor at pin 5, while VR3 adjusts the frequency over a small range. Changing the capacitor to 10nF should increase the frequency sufficiently so it cannot be heard.

Note that increasing the frequency may affect the slow-speed control. This is because, due to motor winding inductance, the frequency may be too high to allow the motor to run at a sufficient speed, although it will jump to full speed at the controller's maximum speed setting. The 2008 version has frequency adjustment in the settings, with a range that is set by the software.

More Grunt Wanted From Induction Motor Speed Controller

I have built the Induction Motor Speed Control kit (purchased through Jaycar) and it works very well, except that my motor (a pool pump) is rated at the top end. While the controller is happy to run it all day, it has trouble starting the motor. About 40% of the time, the motor fails to start and the red fault LED lights.

I suspect my success or failure may be dependent on supply voltage as mine is perhaps on the low end at about 220V. I have reduced the acceleration ramp rate to almost minimum. There is a very small adjustment window where I have a greater chance of the motor starting. Any setting above the very low rate will always result in a failed start.

So is there a way of getting an extra few percent out of the circuit (a modification)? Given that once running the motor is below the rating of the kit and runs flawlessly all day, I have no concerns regarding increasing its rating slightly and thereby reducing the designed safety margin. (J. C., via email).

- There are ways to eke out slightly more power from the unit but you have to be careful since it involves reducing the safety margin in the protection circuitry.

What you are probably running into is a peak current limitation. This is controlled by the value of the surface-mount shunt resistor which we specified as 15 milliohms (15mΩ). We found that on our prototype, we couldn't start the test pump under load with any higher value than this so its value is quite critical. Too low and you run the risk of blowing the IGBT bridge under an overload condition, too high and it won't start the motor.

The easiest approach would be for you to solder a second, higher-value resistor on top of your existing shunt (which is generally quite easy to do) to slightly lower the resistance. Paralleling a 0.22Ω SMD resistor will make the overall resistance about 14mΩ, giving you another 7% peak current before the cut-out kicks in. If you use a 0.1Ω resistor instead, that reduces the resistance to 13mΩ, for a 15% increase in peak current.

We would be very reluctant to go much lower than that. Try the 0.22Ω resistor first, since you want to use the highest resistance you can get away with, so that the IGBT bridge is still well-protected.

You could of course simply replace the resistor with a slightly lower value part but these will be harder to get and it's extra work to remove the existing resistor.

Here are some which you could try:

http://au.element14.com/bourns/crm2512-jx-r100elf/resistor-thick-film-0-1-ohm-2w/dp/1795267
http://au.element14.com/yageophycomp/rl2512fk-070r22l/resistor-2512-1-0r22/dp/1779465

an Aussie car coil (Commodore) in a Silicon Chip project, such coils are hard to find over here.

I have seen a possible substitute at the www.europarts.com website but I have no idea whether it would work. It looks like a 4-terminal device but that is no guarantee of success. If not, can you recommend an alternative cheap one? Would any 4-terminal car ignition coil probably work? (M. K., Brighton, UK).

- Ideally it would be best to use the nominated coil for the Jacob's Ladder. These can also be obtained quite cheaply on-line from the USA as the same V6 3.8-litre engine was used in number of GM cars over there. As an example, see www.ebay.com/itm/1999-Firebird-Camaro-V6-3800-used-ignition-coils-all-3-/171179895571?pt=Motors_Car_Truck_Parts_Accessories&hash=item27db1

Better still, search on a USA website for a DR39 coil. These are the same coil as we specified and again, widely used in General Motors' cars with V6 engines – see www.ebay.com/ctg/Standard-Motor-Products-DR39-Ignition-Coil-/99155612

Alternatively, some double-ended coils for V-twin motorbikes (eg, Harley Davidson) can probably be adapted.

Third, any single output ignition coil (single coil, not multiple coil modules) can probably be adapted. The discharge wires should then be connected between the HV output and GND, as for a conventional ignition system (eg, our High Energy Ignition system from the November & December 2012 issues).

WARNING!

Silicon Chip magazine regularly describes projects which employ a mains power supply or produce high voltage. All such projects should be considered dangerous or even lethal if not used safely.

Readers are warned that high voltage wiring should be carried out according to the instructions in the articles. When working on these projects use extreme care to ensure that you do not accidentally come into contact with mains AC voltages or high voltage DC. If you are not confident about working with projects employing mains voltages or other high voltages, you are advised not to attempt work on them. Silicon Chip Publications Pty Ltd disclaims any liability for damages should anyone be killed or injured while working on a project or circuit described in any issue of Silicon Chip magazine.

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Studio Series headphone amplifier

I am about to construct your November 2005 Studio Series Headphone Amplifier from an Altronics kit. I note that after the output stage is a network of four components: a paralleled inductor coil and 47Ω resistor in series with the output, and a series 10Ω resistor and 47nF capacitor in parallel with the output. I assume that this network is there to ensure stability of the amplifier?

I was wondering how essential this output network is and would it be possible to either remove it completely or at least reduce the series resistor in value? If I did so, what kinds of risks would I be taking?

The reason for my wanting to make these kinds of changes is to reduce the output impedance of the amplifier as much as possible. I would be using the amplifier with headphones of at least 32Ω impedance. I note that there is a circuit design on the web very similar to this which has no similar output network. (P. T., via email).

● We strongly recommend that you do not remove the output filter components. These are included to ensure that the headphone is stable with a wide range of loading conditions. The 47Ω resistor has no effect on the output impedance since it is shunted by the 4.7μH inductor.

To put it another way, removing those components would have no effect on the headphone drive (after all, we do quote performance when driving 8Ω headphones) and it would make it prone to supersonic oscillation.

120W solar-powered lighting system

In the past, I have successfully made three Solar-Powered Lighting Systems from scratch so I think I have a good grasp of the fundamentals of the circuit if not the PIC software.

I have recently embarked on a more ambitious solar lighting system for the garden using your far more powerful 120W MPPT charger which I have also built successfully. Since the newer 120W charger has no facility to control lights I hit on the idea of using the LDR light control and Mosfet switching circuit from the smaller 5W unit.

To this end, I designed a PCB including the necessary elements of the small circuit, at the same time taking care of the now unused PIC circuit pins by tying them either to ground or +5V. The PIC16F88 software was left unaltered since I assumed that the solar power side of the charger runs from the panel and is virtually unpowered and therefore inactive at night.

The resulting circuit partially works but the LDR does not control the light circuit when darkened although the pushbutton switch turns on the light circuit for about one second when the LDR is darkened.

I have programmed three PICs and they all behave the same. The micro is running because the 2N7000 is switching and the parameter setting function works correctly. What I would like to know is what could be causing this unusual behaviour in this part of the circuit?

I consider that that such a switching module would be useful for other tasks where a very low standby circuit capable of switching several amps is necessary. The night/day and PIR/LDR links could be incorporated for other functions. I would greatly appreciate any help you could give because I feel the software may require some modification to achieve my purpose. (B. T., Churchill, Vic).

● You should be able to use the output driver section of the Solar Lighting Controller from May 2010 on its own without the solar charger section. The AN1, AN3 and AN4 inputs should be tied to 0V (not 5V) and the PWM output should be left unconnected, not tied to 0V or 5V. Similarly, the charge LED output at pin 10 should be left unconnected.

You would still need to monitor the battery at the AN2 input so that the low battery switch-off will work and

Query On Lithium-Polymer Battery S

I note that you suggest a 22.2V Lithium Polymer battery pack (with a full-charge voltage of 25.2V) as a substitute for an 18V Nicad or NiMH drill battery pack (December 2013 issue, page 98). I am not sure I would agree with this. An 18V Nicad pack (usually 15 cells at a nominal voltage of 1.2V) should never exceed 22.5V. A fully charged cell is typically 1.45V or so, so a full pack should be less than 21.75V. (A. L., Chippendale, NSW).

● It's true that a typical full charge voltage for a Nicad or NiMH cell is quoted as 1.45V but it can be higher than this. It depends on the exact cell chemistry, ambient temperature, charge rate, how good the charger's termination logic is and so on.

While it's far from definitive, this website has some useful information: http://robocup.mi.fu-berlin.de/buch/chap6/ComparisonBattery.html

Note the graphs of charge voltage versus final capacity, rate and temperature. When charged at a rate of 1C, those particular cells reached about 1.55V at 20°C at 100% charge (1.5V at 1/10C rate) and terminated with an even higher voltage if the ambient temperature was lower.

We have certainly measured NiMH cells fresh out of a fast charger at around 1.6V p stay that high ' tool needs to . That would give a . an output of around 2.

The 6-cell Li-Ion/Li-Po p. maintain its voltage at this le. much longer but overall, that's a better result. If you did not like the concept of using such a high voltage for an 18V Nicad/NiMH pack you could fit a 5-cell Li-Po/Li-Ion pack which will give a much closer match in terms of both nominal and full-charge voltage.

An example of a 5-cell Li-Po pack is the ZIPPY Flightmax 2450mAh 5S1P 30C from Hobby King – see www.hobbyking.com/hobbyking/store/__9929__ZIPPY_Flightmax_2450mAh_5S1P_30C.html

This is nominally 18.5V, fully charged at 21V and discharged at around 16.5V. But we don't think using a 6-cell pack is likely to cause any real problems unless you're really pushing the tool hard (ie, running it almost continuously at low speeds and high torques).

There are many other similar batteries available, as shown here: http://www.hobbyking.com/hobbyking/store/RC_PRODUCT_SEARCH.asp?strSearch=5s1p

Servicing Coffee Machines With Simulated Sensors

I work as a service technician on coffee machines of various types. Unfortunately, we have no easy way of testing the outputs from the control boards without actually fitting them into a machine and trying them out, so I wish to assemble a virtual machine for this purpose.

I can use a wiring loom from a machine and some bezels in place of coils etc but I am stuck on how to replace the flow meters and temperature probe. The flow meters are made by Gicar, with a 3-pin plug on top (positive, negative and earth) and have an impeller that spins as the water runs through, sending a signal back to the control board.

The temperature probe is a thermocouple encased in a metal tube which will only switch the machine when a certain temperature is reached. Also would I need a resistor in place of the pump/motor?

One last thing: is it possible to incorporate both the Tiny Tim Stereo Amplifier and the Stereo Compressor from the January 2012 issue into one unit to listen to TV with even sound output? (E. E., via email).

● Yes, the flow metering and thermocouple could be simulated. The flow meter could be as simple as a 555 timer set up as an oscillator that provides the same frequency output as a working coffee machine flow meter. If necessary, the 555 output could be fed to an NPN transistor for an open-collector output that simulates the flow meter.

The thermocouple simulation would require a small voltage to simulate the probe output. Whether the voltage should be floating above the 0V supply or not does depend on the circuitry of the controller.

Perhaps the best solution would be to use a cell to provide the floating power source, with the voltage divided down using a resistive divider. The divider should only be connected when the test is under way or the cell will be discharged.

Note that the output voltage from the divider will need to be very low, since a K-type thermocouple only produces around 41µV per °C. That is 410µV at 100°C.

The Tiny Tim Stereo Amplifier and the Stereo Compressor could be built into a single case if you wish. The PCBs may need to be stacked vertically with say the compressor mounted on the case lid and the amplifier on the base in order to save space.

so that the Lights will be switched on with sufficient battery voltage. The remaining pins would be used for the lighting circuit. The software should not need changing.

Without seeing your revised circuit of the solar lighting controller, we are unable to offer any further suggestions as to why your modifications are not successful.

Battery LifeSaver component substitute

I have some comments on the Battery Lifesaver (Silicon Chip, September 2013). The MCP6541-E/SN is no longer stocked by element14. If we substitute the MCP6541-I/SN, what are the implications of the reduced temperature range on the maximum current that the unit can handle? Alternatively, the PCB could be designed to use an MCP6542-E/SN and just wire the inputs of the second comparator to the supply rails as shown in the data sheet. Of course, the unit will then draw another 600nA.

The text on page 66 states: "The other half of D1/D2 clamps input pin 3 of IC1 to the 5V supply if the battery voltage is particularly high". This isn't quite accurate, since the common cathode of D1 & D2 connects to the input of REG1 rather than to its output. The input to REG1 could be up to 16V, allowing pin 3 of IC1 to go well beyond V_{DD} + 0.3V, potentially (according to the data sheet) causing damage or improper operation of the comparator.

This potential problem could be avoided by disconnecting A1 of D1/D2 from the circuit and connecting a single Schottky diode between the output of REG1 and pin 3 of IC1 (cathode to REG1 output). The remaining diode in D1/D2 could then also be replaced by a single diode. (A. P., Toowoomba East, Qld).

● We don't think it's critical if you can't get the MCP6541-E version. It was specified because it barely cost any more than the industrial temperature range version and we figured the unit is quite likely to be jammed into a battery compartment with little air

continued on page 103

Notes & Errata

SemTest Discrete Semiconductor Test Set, February-May 2012: the electrolytic capacitor shown just to the upper left of IC4 in the circuit diagram (page 73, March 2012) is shown with a value of 47µF, whereas it should have the value 220µF. The parts list and PCB overlay are both correct.

In addition, the parts list on page 77 has two errors: there should be two 2.2kΩ resistors listed for the main PCB (not one), while the two 2.2kΩ resistors listed for the display PCB are not required.

CLASSiC DAC, February-May 2013: on the PCB layout diagram (Fig.11, p39, April 2013), the 1.5kΩ resistor just to the left of CON12 (near centre) should be 470Ω. There are also two parts list errors: (1) two 220µF 10V electrolytic capacitors should be included in the list; and (2) instead of 14 x 100µF 16V electrolytic capacitors, the list should show 12 x 100µF 16V and 2 x 100µF 25V capacitors.

Repacking a Cordless Drill With A Lithium Battery Pack, October 2013: the wiring diagram of Fig.1 on page 14 shows the Battery Lifesaver incorrectly wired, with the terminations to B- and L- swapped. The L- terminal should go to to the negative side of the drill motor and the B- terminal should have the negative battery and charger wires connected to it.

This will not cause any immediate damage but the drill current will pass via the substrate diode of the Mosfet and therefore the Battery LifeSaver will offer no protection to the Lithium battery itself.

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to circulate. But the dissipation of the Mosfet at 20A is only about 0.5W and a bit over 1W at 30A. The real question with regards to how hot the PCB will get is how much additional dissipation there will be in the PCB itself, the wiring and the solder joints etc.

You would have to push it really hard to get the comparator beyond 85°C and even then it would be unlikely to fail. The 'E' versions probably come off the same production line as the 'I' versions but undergo more extensive testing to ensure their parameters don't go out of spec between 85°C and 125°C. So there shouldn't be any real problems with the circuit even

continued on page 104

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Ask Silicon Chip
. . . continued from page 103

if the parameters did get a bit worse than specified (higher leakage, etc). It may shift the cut-off point a bit but that would be it.

As for the diode clamp, you are right but luckily it isn't critical. The divider resistors limit any current that might flow into the comparator's input clamp diode to a safe level.

Li'l Pulser controller is unresponsive

I am currently building the Li'l Pulser Train Tontroller kit (Silicon Chip, July 2013). However, the pot doesn't seem to dial the voltage up or down and the brake & inertia switches don't work. It powers up though and will go into reverse and shows 12V on the tracks.

I am using a 12V switchmode power supply out of a PC, if that helps. I have cleaned all flux off and checked for dry joints/solder bridges/broken tracks and all seems good. I am just wondering what I should do? (A. C., via email).

- The Li'l Pulser is designed to be powered from a pulsating 12V DC rail (that means the voltage swings up to around 16V) or from 15-17VDC. Running it from 12V DC will not necessarily work successfully and the regulator's output will only be 10V or so instead of 12V. That may well affect the speed setting range.

The fact that you can select forward and reverse suggests that pin 5 of IC3b is at a low voltage. The output of IC3b, however, is possibly high or the Mosfet is switched on continuously for some other reason.

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One possibility is that transistor Q6 is the wrong type and/or diode D7 is the wrong way around. You will need to check that all components are placed correctly and orientated as shown on the overlay diagram.

Footnote: the reader subsequently discovered that a 470kΩ resistor had been installed in series with VR2 & VR3 instead of 470Ω.

Misleading power ratings on LED lights

I recently purchased four 27W LED floodlights from a local (Perth) eBay store. On testing them on a workshop power supply, I found they only drew 1.25A at 12V. They were rated at 12-24V so I went up to 24V and the current dropped. The power was actually about 15W.

On contacting the supplier, I had to teach him how to use his multimeter and Ohm's Law when he tested one on his car battery. He agreed that they were not drawing 27W as advertised and offered a refund. I said that I would be happy at half the price and he agreed. The money was refunded quickly into my account. He then contacted his supplier and questioned the power rating.

The supplier said that they were 27W as they were fitted with nine 3W LEDs. My supplier left his advertisement as 27W but changed the current draw to 1.25A. The current regulator in the light prevents the rated power from being achieved. These lights are common on eBay and I am curious to know if others think that selling them as 27W with only a 15W power draw is misleading. (C. C., Mosman Park, WA).

- A lot of products sold on the internet have misleading descriptions. Short of asking for a refund or a price reduction, as you did, there is not much else that can be done since any overseas seller is not subject to Australian consumer protection laws. In your case, the seller is subject to Australian law and is legally required to provide a correct description. SC

Advertising Index

Altronics	72-75
Core Electronics	7
Emona Instruments	43
Freetronics	45
Gless Audio	103
Hare & Forbes	OBC
Icom Australia	5
Involve Audio	6
Jaycar	IFC,49-56
Keith Rippon	103
KitStop	93
LD Electronics	103
LED Sales	103
Low Energy Developments	103
Master Instruments	103
Microchip Technology	3
Mikroelektronika	IBC
Micro Engines	6
Ocean Controls	11
PicoKit	10
Quest Electronics	103
Radio, TV & Hobbies DVD	93
RF Modules	104
Sesame Electronics	103
Silicon Chip Binders	11,78
Silicon Chip Bookshop	81
Silicon Chip Online Shop	67
Silicon Chip Subscriptions	19
Television Replacements	103
Wiltronics	9
Worldwide Elect. Components	104
xLogic	8

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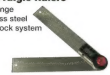

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